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# TRANSMITTAL OF FORMAL DRAWINGS

Docket No. 72478-0200 PAWB 1-24-03

In Re Application Of: **Waki et al.**

| Serial No. | Filing Date | Batch No. | Examiner | Art Unit |
|---|---|---|---|---|
| 09/288,263 | April 8, 1999 | | Christian La Forgia | 2157 |

Invention: **HIGH SPEED VIRTUAL MACHINE AND COMPILER**

Address to:
**Assistant Commissioner for Patents**
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Transmitted herewith are:

**91** sheets of formal drawing(s) for this application.

☒ Each sheet of drawing indicates the identifying indicia suggested in 37 CFR Section 1.84(c).

*Signature*

Dated: **1-14-03**


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I certify that this document and attached formal drawings are being deposited on **1-14-03** with the U.S. Postal Service as first class mail under 37 C.F.R. 1.8 and addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Sandy Malec

*Signature of Person Mailing Correspondence*

**Sandy Malec**

*Typed or Printed Name of Person Mailing Correspondence*

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FIG. 1

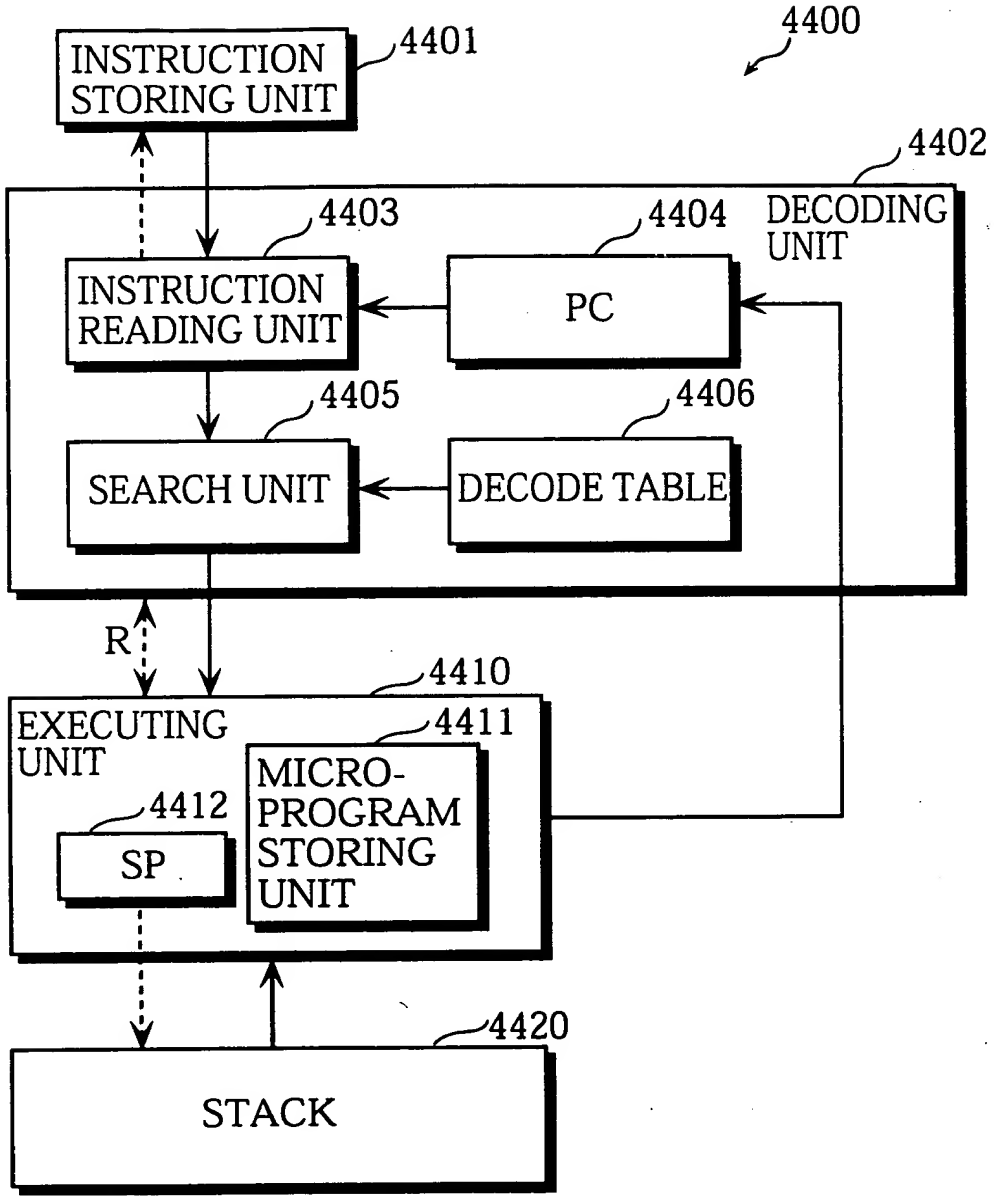

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FIG. 2

| VIRTUAL MACHINE INSTRUCTION | OPERATION CONTENTS | CHANGE IN STACK CONTENTS | SP VALUE |
|---|---|---|---|
| Push | PUSH OPERAND ONTO STACK | s0←operand | sp←sp+1 |
| Pop | POP VALUE OF TOP STACK AND PLACE IT INTO ADDRESS INDICATED BY OPERAND | operand←s0<br>s0←s1 | sp←sp-1 |
| Add | ADD VALUES ON TOP AND SECOND STACKS AND STORE RESULT ONTO STACK TOP | s0←s0+s1 | sp←sp-1 |
| Mult | MULTIPLY VALUES ON TOP AND SECOND STACKS AND STORE RESULT ONTO STACK TOP | s0←s0*s1 | sp←sp-1 |
| Br | JUMP UNCONDITIONALLY TO ADDRESS OF OPERAND | s0←s0 | sp←sp |
| Brz | JUMP TO ADDRESS OF OPERAND IF STACK TOP VALUE IS 0 | DELETE←s0<br>s0←s1 | sp←sp-1 |
| Brnz | JUMP TO ADDRESS OF OPERAND IF STACK TOP VALUE IS NOT 0 | DELETE←s0<br>s0←s1 | sp←sp-1 |
| Call | CALL FUNCTION SPECIFIED BY ADDRESS OF OPERAND | s0←NEXT VIRTUAL MACHINE CODE ADDRESS | sp←sp+1 |
| Ret | JUMP UNCONDITIONALLY TO ADDRESS OF STACK TOP VALUE | DELETE←s0<br>s0←s1 | sp←sp-1 |
| Stop | STOP VIRTUAL MACHINE PROCESSING | INITIAL STATE | sp←0 |

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FIG. 3

4406

| 4406a OPCODE | 4406b JUMP ADDRESS | 4406c NUMBER OF OPERANDS |
|---|---|---|
| : | : | : |
| Push | <JUMP ADDRESS OF CODE TO PERFORM Push> | 1 |
| Pop | <JUMP ADDRESS OF CODE TO PERFORM Pop> | 1 |
| Add | <JUMP ADDRESS OF CODE TO PERFORM Add> | 0 |
| Sub | <JUMP ADDRESS OF CODE TO PERFORM Sub> | 0 |
| Inc | <JUMP ADDRESS OF CODE TO PERFORM Inc> | 0 |
| Dec | <JUMP ADDRESS OF CODE TO PERFORM Dec> | 0 |
| Mult | <JUMP ADDRESS OF CODE TO PERFORM Mult> | 0 |
| Div | <JUMP ADDRESS OF CODE TO PERFORM Div> | 0 |
| : | : | : |

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FIG. 4A

```
MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Push"
1:Inc       r3        ; INCREMENT SP VALUE BY ONE
2:Load      r0,[r2]   ; EXTRACT OPERAND AND
                      ; PLACE IT ONTO REGISTER #0
3:Inc       r2        ; INCREMENT VIRTUAL MACHINE PC BY ONE AND
                      ; PREPARE FOR READING NEXT INSTRUCTION
4:Store     [r3],r0   ; PUSH VALUE OF REGISTER #0 ONTO STACK
<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
```

FIG. 4B

```
MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Add"
1:Load      r0,[r3]   ; EXTRACT VALUE FROM STACK
                      ; PLACE IT ONTO REGISTER #0
2:Dec       r3        ; DECREMENT VALUE OF VIRTUAL MACHINE SP BY ONE
3:Load      r1,[r3]   ; EXTRACT VALUE FROM STACK
                      ; PLACE IT ONTO REGISTER #1
4:Add       r0,r0,r1  ; ADD VALUES OF REGISTER #0 AND #1 AND
                      ; PLACE RESULT ONTO REGISTER #1
5:Store     [r3],r0   ; PLACE VALUE OF REGISTER #0 ONTO STACK
<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
```

FIG. 4C

```
MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Mult"
1:Load      r0,[r3]   ; EXTRACT VALUE FROM STACK AND
                      ; PLACE IT ONTO REGISTER #0
2:Dec       r3        ; DECREMENT VALUE OF VIRTUAL MACHINE SP BY ONE
3:Load      r1,[r3]   ; EXTRACT VALUE FROM STACK AND
                      ; PLACE IT ONTO REGISTER #1
4:Mult      r0,r0,r1  ; MULTIPLY VALUES OF REGISTERS #0 AND #1 AND
                      ; PLACE RESULT ONTO REGISTER #1
5:Store     [r3],r0   ; PLACE VELUE OF REGISTER #0 ONTO STACK
<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
```

FIG. 4D

```
<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
1:Load      r0,[r2]   ; READ VIRTUAL MACHINE INSTRUCTION
                        (JUMP ADDRESS) INDICATED BY PC
                        INTO REGISTER #0
2:Inc       r2        ; INCREMENT VIRTUAL MACHINE PC VALUE BY ONE
3:Jmp       r0        ; JUMP UNCONDITIONALLY TO LOCATION
                        INDICATED BY REGISTER #0
```

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FIG. 5

| REAL MACHINE INSTRUCTION | OPERATION CONTENTS | NOTATION | EXAMPLE |
|---|---|---|---|
| Load | PLACE VALUE OF DESIGNATED REGISTER (x1) OR THAT OF MEMORY LOCATION ([x1]) DESIGNATED BY REGISTER ONTO VALUE OF DESIGNATED REGISTER (x0) | Load x0,x1<br>Load x0,[x1] | Load r0,r1<br>Load r1,[r2] |
| Store | PLACE VALUE OF DESIGNATED REGISTER (x1) ONTO MEMORY LOCATION [x0] DESIGNATED BY REGISTER | Store [x0],x1 | Store [r0],r1 |
| Add | ADD VALUES OF DESIGNATED REGISTERS (x1,x2) , AND PLACE RESULT ONTO DESIGNATED REGISTER (x0) | Add x0,x1,x2 | Add r0,r1,r2 |
| Mult | MULTIPLY VALUES OF DESIGNATED REGISTERS (x1,x2) , AND PLACE RESULT ONTO DESIGNATED REGISTER (x0) | Mult x0,x1,x2 | Mult r0,r1,r2 |
| Inc | ADD 1 TO VALUE OF DESIGNATED REGISTER (x1) , AND STORE RESULT IN SAME REGISTER | Inc x0 | Inc r4 |
| Dec | SUBTRACT 1 FROM VALUE OF DESIGNATED REGISTER (x0) , AND STORE RESULT IN SAME REGISTER | Dec x0 | Dec r3 |
| Jmp | JUMP TO ADDRESS INDICATED BY DESIGNATED REGISTER (x0) | Jmp x0 | Jmp r2 |
| Jz | JUMP TO ADDRESS INDICATED BY DESIGNATED REGISTER (x1) IF VALUE OF DESIGNATED REGISTER (x0) IS 0 | Jz x0,x1 | Jz r0,r2 |
| Jnz | JUMP TO ADDRESS INDICATED BY DESIGNATED REGISTER (x1) IF VALUE OF DESIGNATED REGISTER (x0) IS NOT 0 | Jnz x0,x1 | Jnz r0,r2 |
| Nop | NOTHING PERFORMED | Nop | Nop |

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FIG. 6

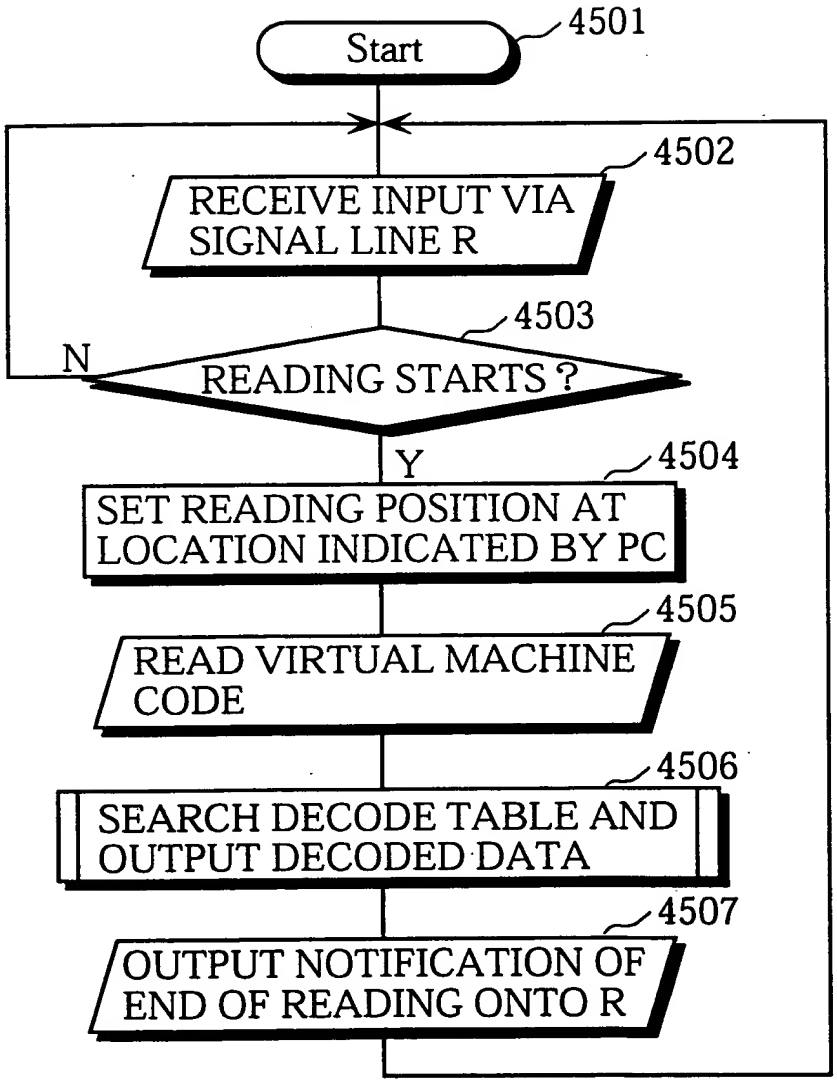

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FIG. 7

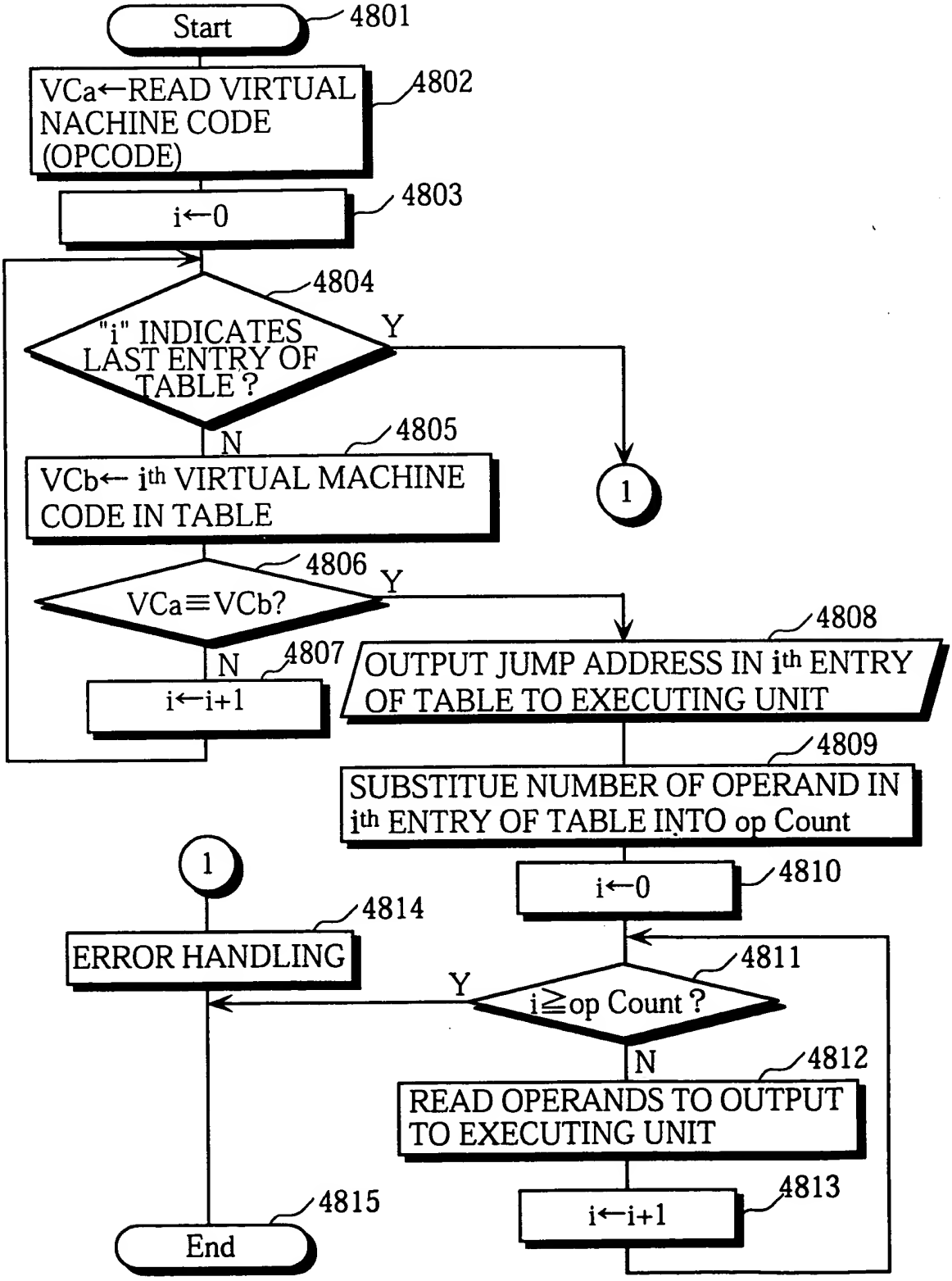

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FIG. 8

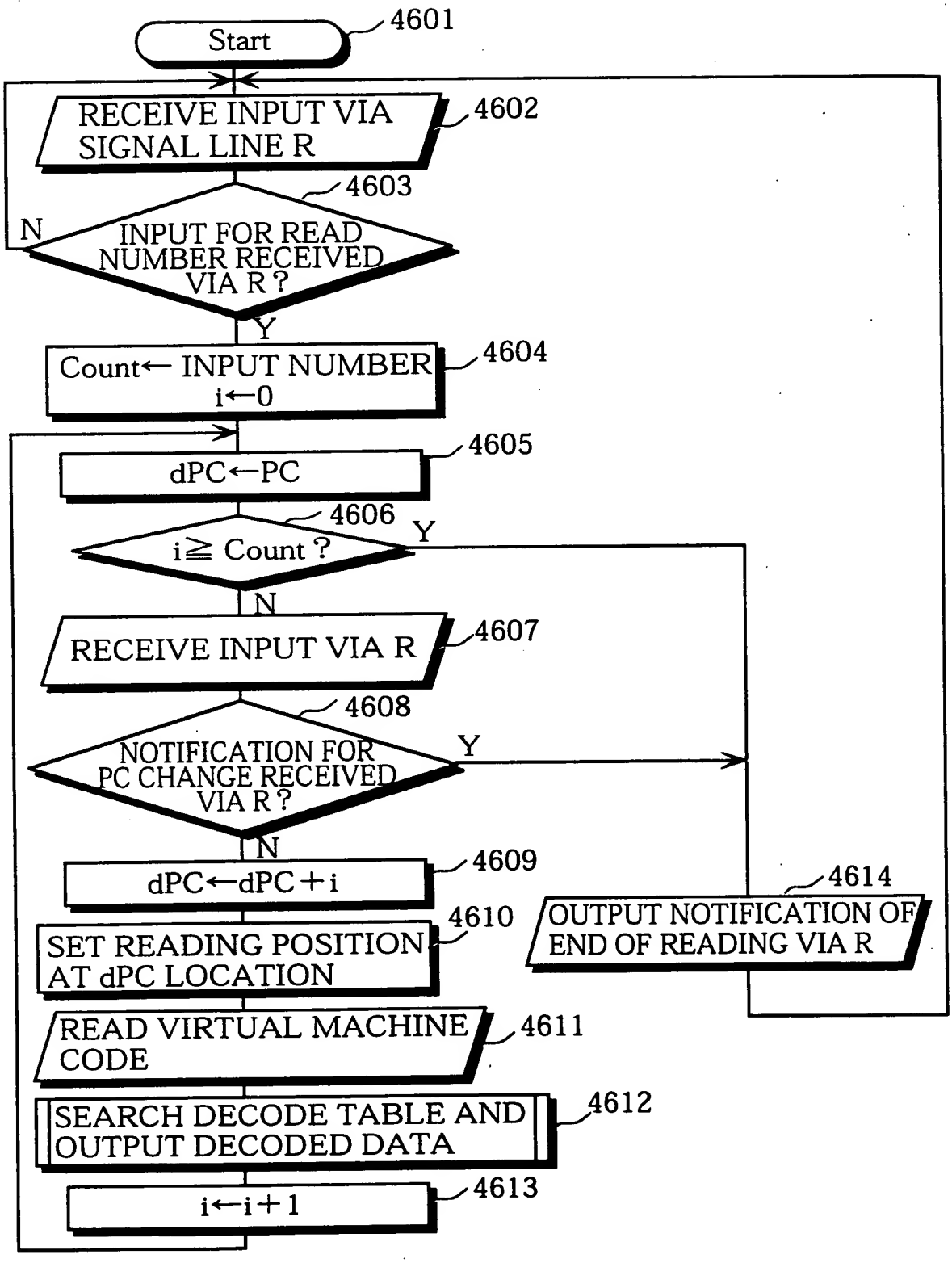

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FIG. 9

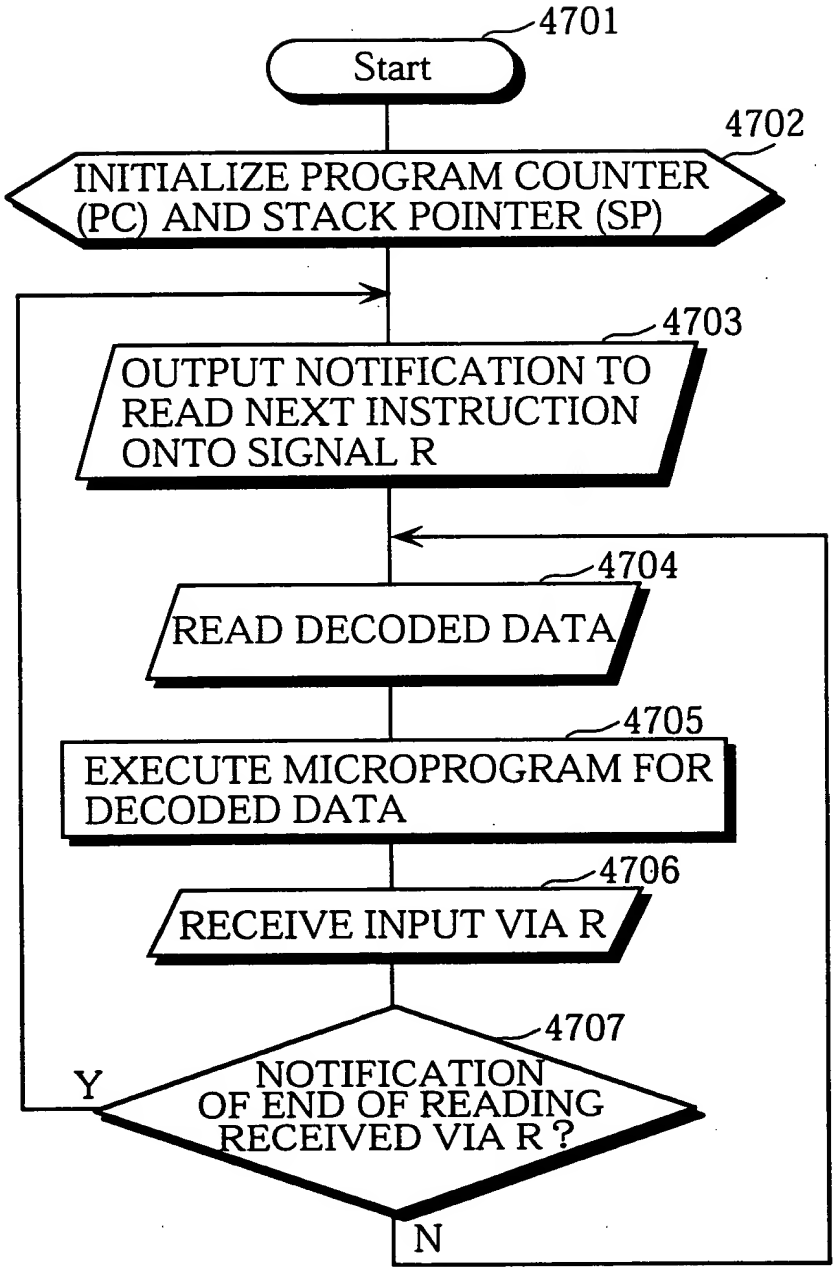

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FIG. 10A

| | |
|---|---|
| 1: | Push |
| 2: | 2 |
| 3: | Push |
| 4: | 3 |
| 5: | Push |
| 6: | 4 |
| 7: | Add |
| 8: | Mult |
| 9: | Pop |
| 10: | 0 |

FIG. 10B

| |
|---|
| ARITHMETIC EXPRESSION : <DATA AREA #0>=2*(3+4) |

FIG. 10C

| |
|---|
| 1: <JUMP ADDRESS OF CODE TO PERFORM Push> |
| 2: OPERAND "2" |
| 3: <JUMP ADDRESS OF CODE TO PERFORM Push> |
| 4: OPERAND "3" |
| 5: <JUMP ADDRESS OF CODE TO PERFORM Push> |
| 6: OPERAND "4" |
| 7: <JUMP ADDRESS OF CODE TO PERFORM Add> |
| 8: <JUMP ADDRESS OF CODE TO PERFORM Mult> |
| 9: <JUMP ADDRESS OF CODE TO PERFORM Pop> |
| 10: OPERAND "0" |

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FIG. 11A

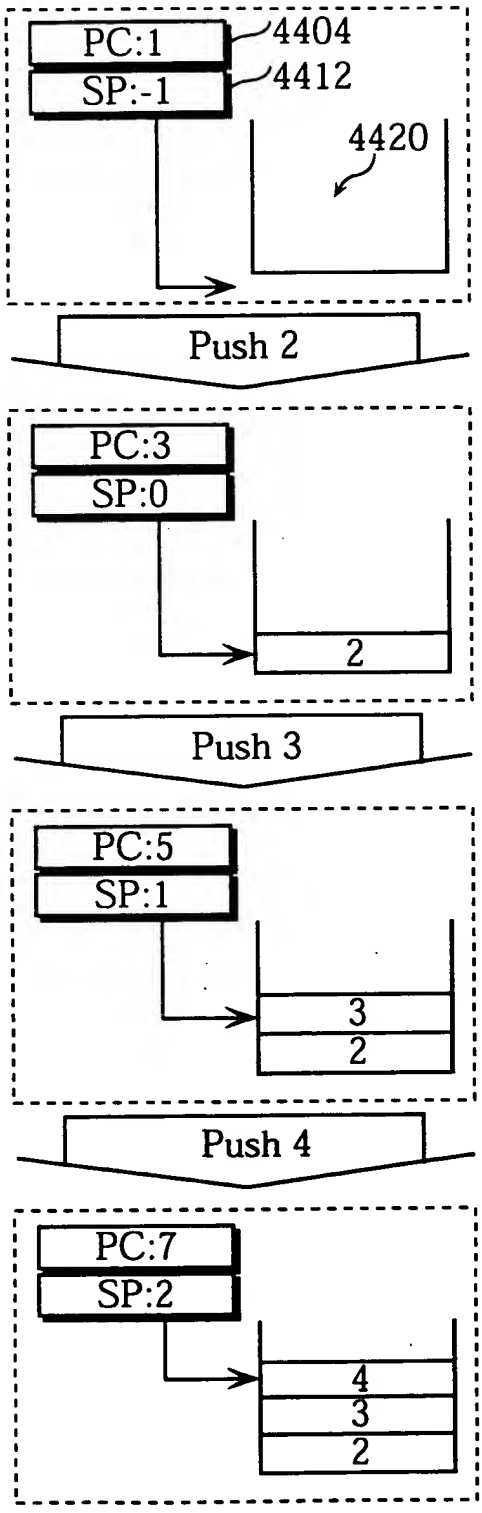


FIG. 11B

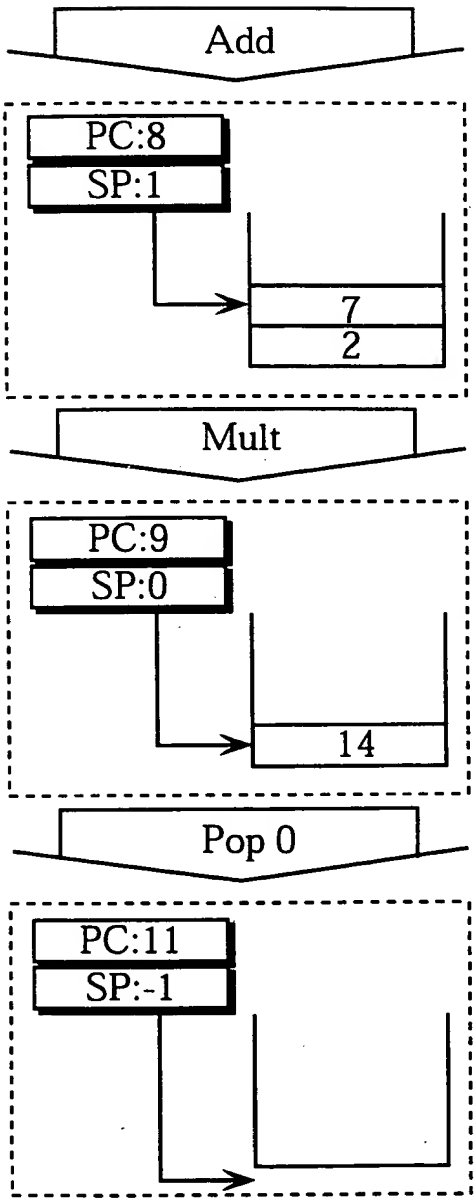

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FIG. 12A

```
MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Push"

1:Inc      r3          ; INCREMENT SP VALUE BY ONE
2:Store    [r3],r0     ; PLACE VALUE OF TOS REGISTER (#0)
                       ; INTO STACK
3:Load     r0,[r2]     ; EXTRACT OPERAND AND
                       ; PLACE IT ONTO TOS REGISTER
4:Inc      r2          ; INCREMENT PC OF VIRTUAL MACHINE BY ONE TO PREPARE
                       ; FOR READING NEXT INSTRUCTION

<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
```

FIG. 12B

```
MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Add"

1:Load     r1,[r3]     ; EXTRACT VALUE FROM STACK
                       ; PLACE IT ONTO REGISTER #1
2:Dec      r3          ; DECREMENT VALUE OF VIRTUAL MACHINE PC BY ONE
3:Add      r0,r0,r1    ; ADD VALUES OF REGISTERS #0 AND #1 AND
                       ; PLACE RESULT ONTO TOS REGISTER

<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
```

FIG. 12C

```
MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Mult"

1:Load     r1,[r3]     ; EXTRACT VALUE FROM STACK AND
                       ; PLACE IT ONTO REGISTER #1
2:Dec      r3          ; DECREMENT VALUE OF VIRTUAL MACHINE SP BY ONE
3:Mult     r0,r0,r1    ; MULTIPLY VALUES OF REGISTERS #0 AND #1 AND
                       ; PLACE RESULT ONTO TOS REGISTER

<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>
```

FIG. 12D

```
<MICROPROGRAM FOR JUMPING TO NEXT VIRTUAL MACHINE INSTRUCTION>

1:Load     r1,[r2]     ; READ VIRTUAL MACHINE INSTRUCTION (JUMP ADDRESS)
                       ; INDICATED BY PC INTO REGISTER #1

2:Inc      r2          ; INCREMENT VIRTUAL MACHINE PC BY ONE
3:Jmp      r1          ; JUMP UNCONDITIONALLY TO LOCATION
                         INDICATED BY REGISTER #1
```

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FIG. 13A

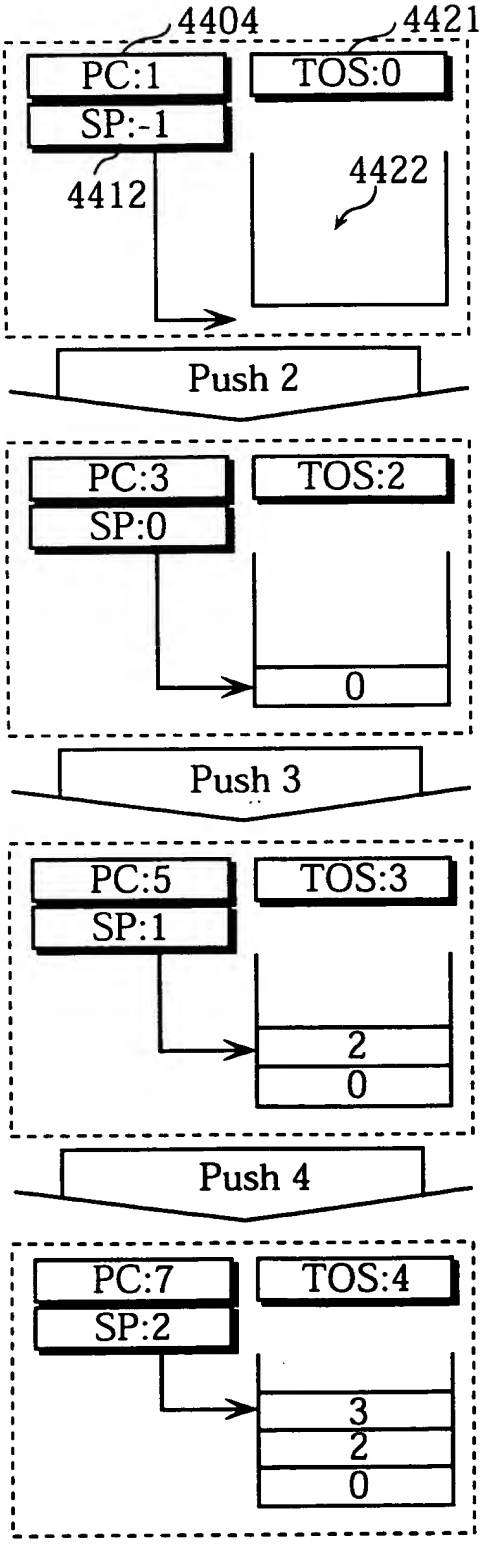


FIG. 13B

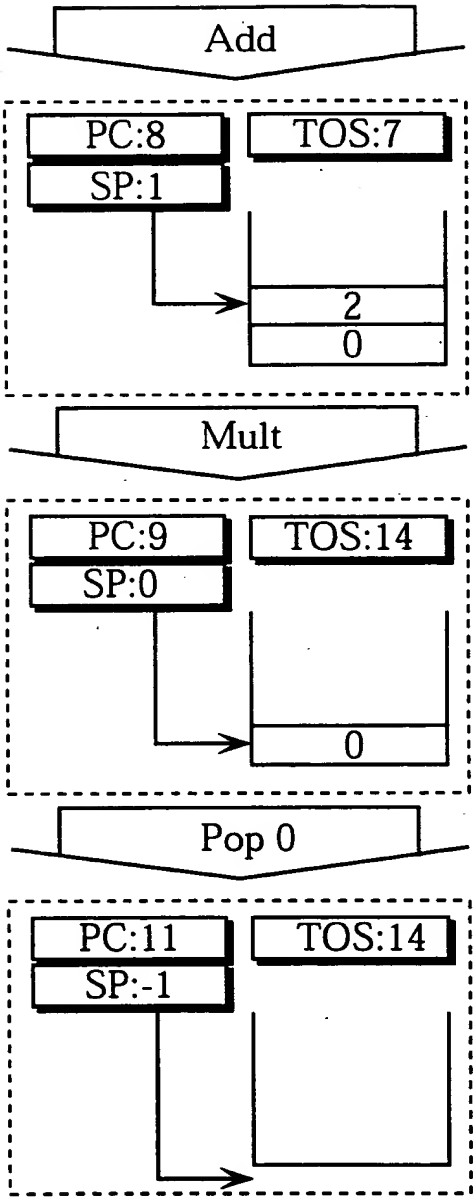

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FIG. 14

| STAGE NAME | NOTATION |
|---|---|
| INSTRUCTION FETCH | IF |
| INSTRUCTION DECODE AND REGISTER REFERENCE | RF |
| EXECUTION | ALU |
| MEMORY ACCESS | MEM |
| RESULT WRITING TO REGISTER | WB |

FIG. 15

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| INSTRUCTION A | IF | RF | ALU | MEM | WB | | | |
| INSTRUCTION B | | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION C | | | IF | RF | ALU | MEM | WB | |
| INSTRUCTION D | | | | IF | RF | ALU | MEM | WB |

FIG. 16

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| INSTRUCTION A1 | IF | RF | ALU | MEM | WB | | | |
| INSTRUCTION A2 | IF | RF | ALU | MEM | WB | | | |
| INSTRUCTION B1 | | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION B2 | | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION C1 | | | IF | RF | ALU | MEM | WB | |
| INSTRUCTION C2 | | | IF | RF | ALU | MEM | WB | |
| INSTRUCTION D1 | | | | IF | RF | ALU | MEM | WB |
| INSTRUCTION D2 | | | | IF | RF | ALU | MEM | WB |

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FIG. 17

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| INSTRUCTION A | IF | RF | ALU | MEM | WB | | | | |
| INSTRUCTION B | | IF | RF | • | ALU | MEM | WB | | |
| INSTRUCTION C | | | IF | • | RF | ALU | MEM | WB | |
| INSTRUCTION D | | | | • | IF | RF | ALU | MEM | WB |

FIG. 18

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| INSTRUCTION A1 | IF | RF | ALU | MEM | WB | | | | |
| INSTRUCTION A2 | IF | RF | ALU | MEM | WB | | | | |
| INSTRUCTION B1 | | IF | RF | • | ALU | MEM | WB | | |
| INSTRUCTION B2 | | IF | RF | ALU | MEM | WB | | | |
| INSTRUCTION C1 | | | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION C2 | | | IF | RF | • | ALU | MEM | WB | |
| INSTRUCTION D1 | | | | IF | RF | ALU | MEM | WB | |
| INSTRUCTION D2 | | | | IF | RF | • | ALU | MEM | WB |

FIG. 19

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| INSTRUCTION A | IF | RF | ALU | MEM | WB | | | | | |
| INSTRUCTION B | | IF | RF | • | • | ALU | MEM | WB | | |
| INSTRUCTION C | | | IF | • | • | RF | ALU | MEM | WB | |
| INSTRUCTION D | | | | • | • | IF | RF | ALU | MEM | WB |

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FIG. 20

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| INSTRUCTION A1 | IF | RF | ALU | MEM | WB | | | | |
| INSTRUCTION A2 | IF | RF | ALU | MEM | WB | | | | |
| INSTRUCTION B1 | | IF | RF | • | • | ALU | MEM | WB | |
| INSTRUCTION B2 | | IF | RF | ALU | MEM | WB | | | |
| INSTRUCTION C1 | | | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION C2 | | | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION D1 | | | | IF | RF | ALU | MEM | WB | |
| INSTRUCTION D2 | | | | IF | RF | • | ALU | MEM | WB |

FIG. 21

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| INSTRUCTION A | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION B | | IF | x | | | | |
| INSTRUCTION C | | | IF | RF | ALU | MEM | WB |

FIG. 22

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| INSTRUCTION A1 | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION A2 | IF | RF | ALU | MEM | WB | | |
| INSTRUCTION B1 | | IF | x | | | | |
| INSTRUCTION B2 | | IF | x | | | | |
| INSTRUCTION C1 | | | IF | RF | ALU | MEM | WB |
| INSTRUCTION C2 | | | IF | RF | ALU | MEM | WB |

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FIG. 23

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | | |
| Inc r2 | | IF | RF | ALU | MEM | WB | | | | | |
| Jmp r1 | | | IF | RF | ALU | MEM | WB | | | | |
| | | | | IF | x | | | | | | |
| Load r1,[r3] | | | | | IF | RF | ALU | MEM | WB | | |
| Dec r3 | | | | | | IF | RF | ALU | MEM | WB | |
| Mult r0,r0,r1 | | | | | | | IF | RF | ALU | MEM | WB |

FIG. 24

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | | |
| Inc r2 | IF | RF | ALU | MEM | WB | | | | | | |
| Jmp r1 | | IF | RF | • | ALU | MEM | WB | | | | |
| | | IF | RF | ALU | x | | | | | | |
| | | | IF | RF | x | | | | | | |
| | | | IF | RF | x | | | | | | |
| | | | | IF | x | | | | | | |
| | | | | IF | x | | | | | | |
| Load r1,[r3] | | | | | IF | RF | ALU | MEM | WB | | |
| Dec r3 | | | | | IF | RF | ALU | MEM | WB | | |
| Mult r0,r0,r1 | | | | | | IF | RF | • | ALU | MEM | WB |

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FIG. 25

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | | | | |
| Inc r2 | | IF | RF | ALU | MEM | WB | | | | | | | |
| Jmp r1 | | | IF | RF | • | ALU | MEM | WB | | | | | |
| | | | | IF | • | x | | | | | | | |
| Load r1,[r3] | | | | | • | IF | RF | ALU | MEM | WB | | | |
| Dec r3 | | | | | | | IF | RF | ALU | MEM | WB | | |
| Mult r0,r0,r1 | | | | | | | | IF | RF | • | ALU | MEM | WB |

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FIG. 26

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | | | | |
| Inc r2 | IF | RF | ALU | MEM | WB | | | | | | | | |
| Jmp r1 | | IF | RF | • | • | ALU | MEM | WB | | | | | |
| | | IF | RF | ALU | MEM | x | | | | | | | |
| | | | IF | RF | ALU | x | | | | | | | |
| | | | IF | RF | ALU | x | | | | | | | |
| | | | | IF | RF | x | | | | | | | |
| | | | | IF | RF | x | | | | | | | |
| | | | | | IF | x | | | | | | | |
| | | | | | IF | x | | | | | | | |
| Load r1,[r3] | | | | | | IF | RF | ALU | MEM | WB | | | |
| Dec r3 | | | | | | IF | RF | ALU | MEM | WB | | | |
| Mult r0,r0,r1 | | | | | | | IF | RF | • | • | ALU | MEM | WB |

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FIG. 27

```
 0:Push    0       ;i←0
 2:Pop     [0]
 4:Push    0       ;sum←0
 6:Pop     [1]

 8:Push    [0]     ;i<10 ?
10:Push    10
12:Sub
13:Brz     31

15:Push    [1]     ;sum←sum+i
17:Push    [0]
19:Add
20:Pop     [1]
22:Push    [0]     ;i←i+1
24:Push    1
26:Add
27:Pop     [0]
29:Br      8

31:Stop
```

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FIG. 28

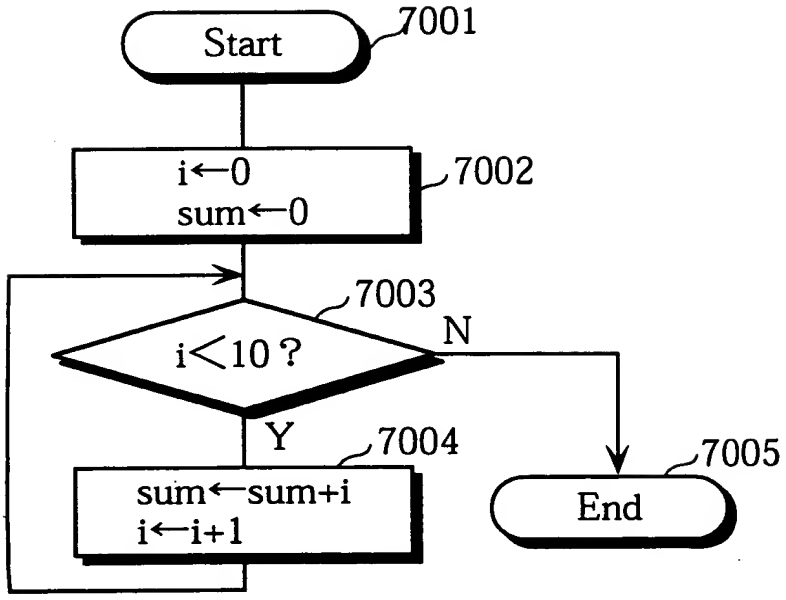

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FIG. 29

| VIRTUAL MACHINE INSTRUCTION | SIZE OF REAL MACHINE CODE TEMPLATE | REAL MACHINE CODE TEMPLATE | NUMBER OF OPERANDS |
|---|---|---|---|
| : | : | : | : |
| Push | 4 WORDS | <CODE TO PERFORM Push> | 1 |
| Pop | 5 WORDS | <CODE TO PERFORM Pop> | 1 |
| Add | 3 WORDS | <CODE TO PERFORM Add> | 0 |
| Sub | 3 WORDS | <CODE TO PERFORM Sub> | 0 |
| Mult | 3 WORDS | <CODE TO PERFORM Mult> | 0 |
| Push[] | 5 WORDS | <CODE TO PERFORM Push[]> | 1 |
| Br | 3 WORDS | <CODE TO PERFORM Br> | 1 |
| Brz | 5 WORDS | <CODE TO PERFORM Brz> | 1 |
| Stop | 2 WORDS | <CODE TO PERFORM Stop> | 0 |
| : | : | : | : |

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FIG. 30

| VIRTUAL MACHINE CODE ADDRESS | VIRTUAL MACHINE CODE | REAL MACHINE CODE SIZE | CORRESPONDING REAL MACHINE CODE ADDRESS |
|---|---|---|---|
| 0 | Push 0 | 4 | 0-3 |
| 2 | Pop [0] | 5 | 4-8 |
| 4 | Push 0 | 4 | 9-12 |
| 6 | Pop [1] | 5 | 13-17 |
| 8 | Push [0] | 5 | 18-22 |
| 10 | Push 10 | 4 | 23-26 |
| 12 | Sub | 3 | 27-29 |
| 13 | Brz 31 | 5 | 30-34 |
| 15 | Push [1] | 5 | 35-39 |
| 17 | Push [0] | 5 | 40-44 |
| 19 | Add | 3 | 45-47 |
| 20 | Pop [1] | 5 | 48-52 |
| 22 | Push [0] | 5 | 53-57 |
| 24 | Push 1 | 4 | 58-61 |
| 26 | Add | 3 | 62-64 |
| 27 | Pop [0] | 5 | 65-69 |
| 29 | Br 8 | 3 | 70-72 |
| 31 | Stop | 2 | 73-75 |

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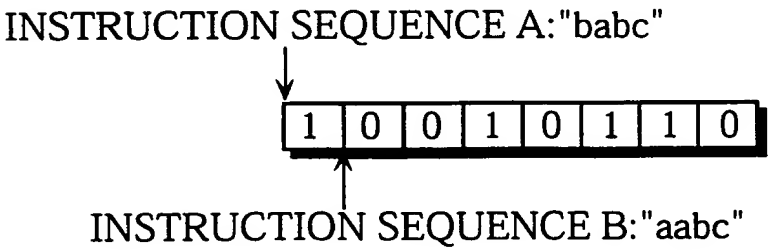
FIG. 31A

9300a 9300b

| BIT SEQUENCE | MEANING |
|---|---|
| 0 | "a" |
| 10 | "b" |
| 110 | "c" |
| 111 | "d" |

FIG. 31B



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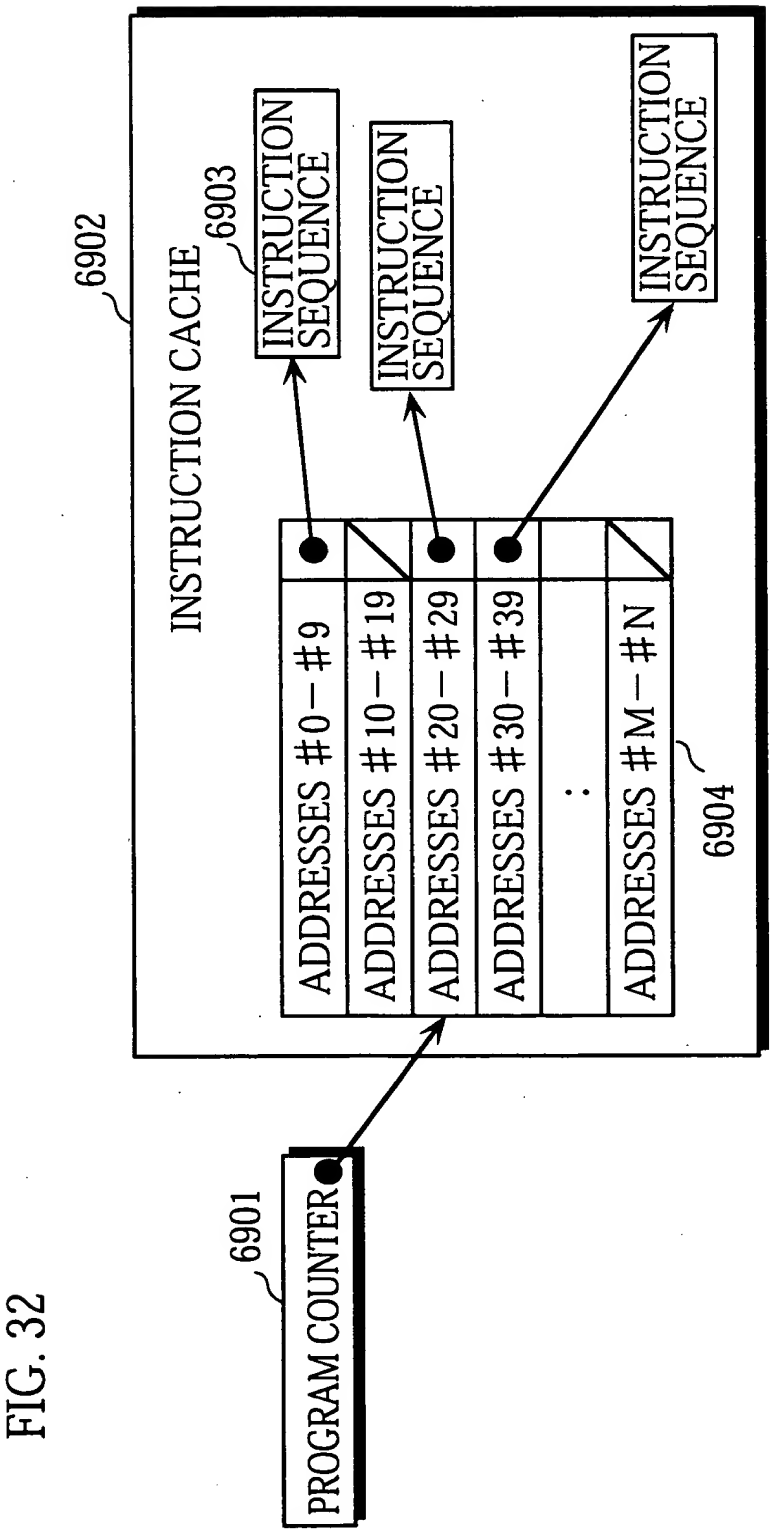


FIG. 32

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FIG. 33

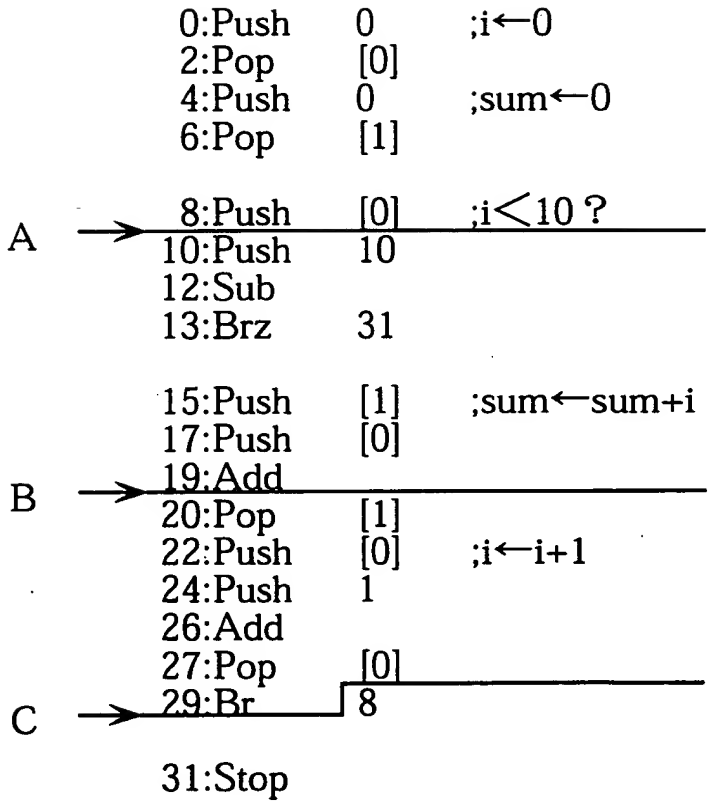

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FIG. 34

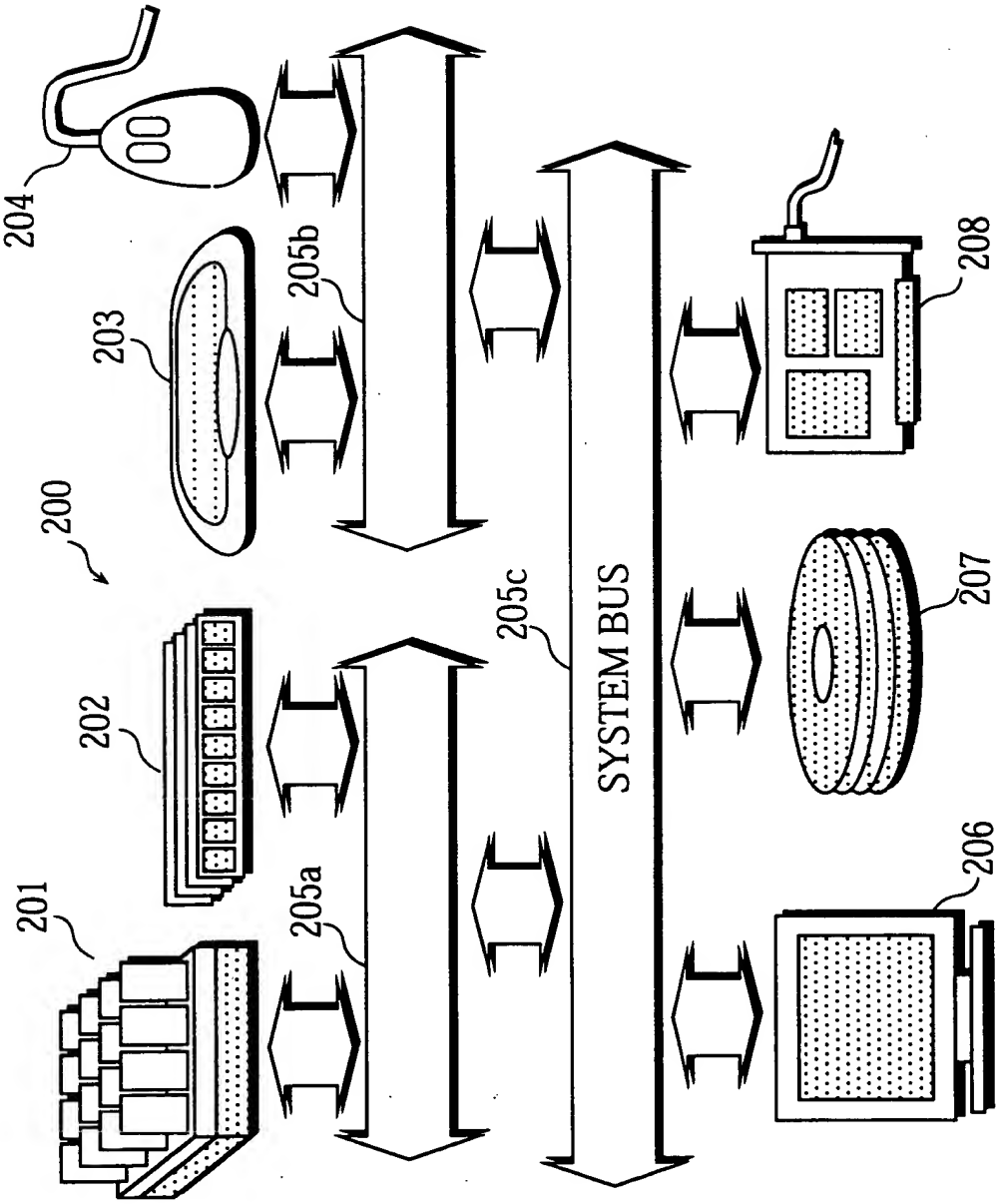

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FIG. 35

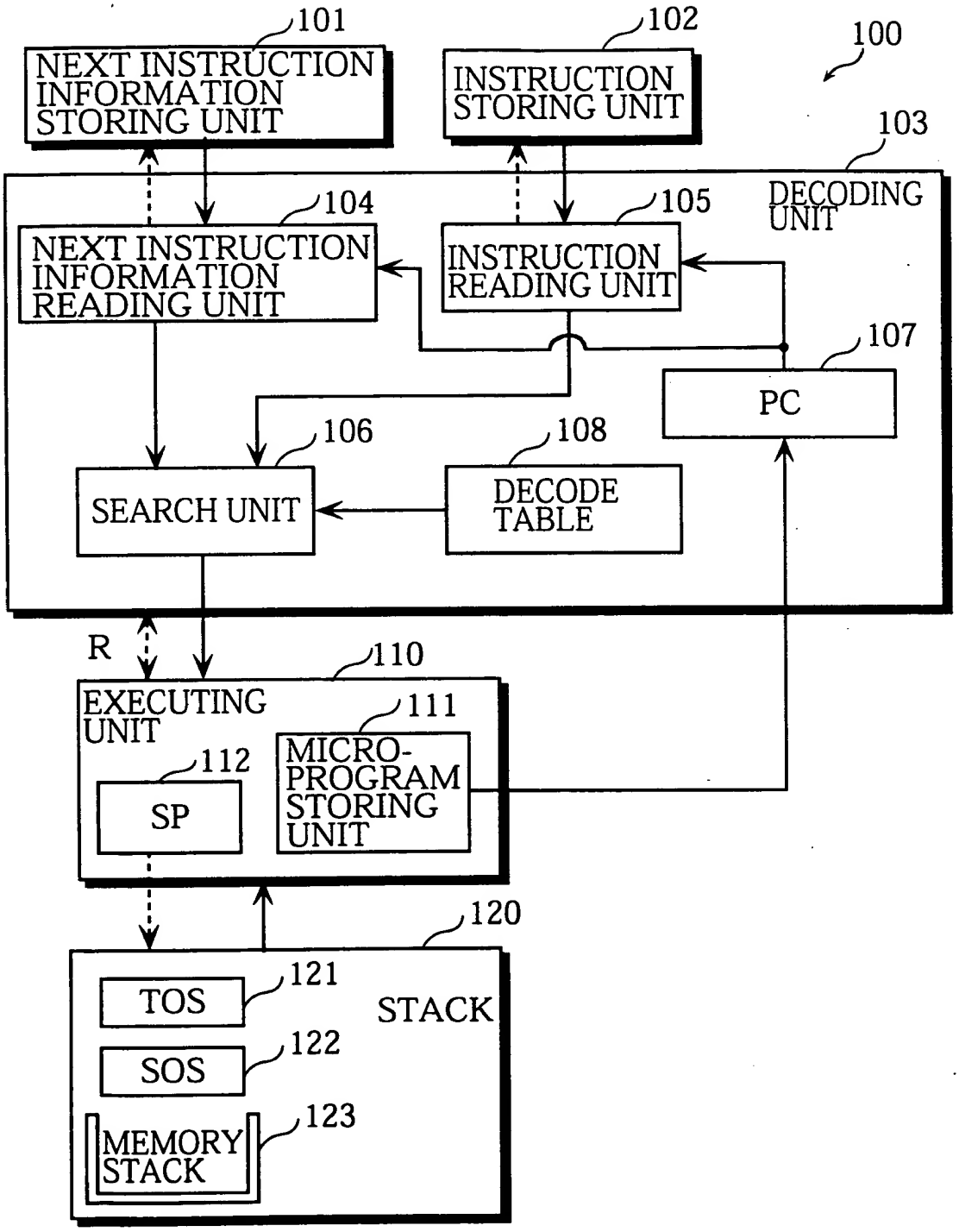

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FIG. 36A

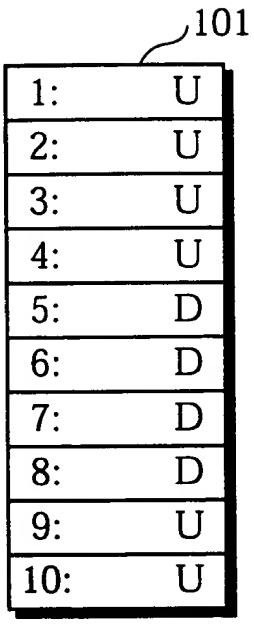


FIG. 36B

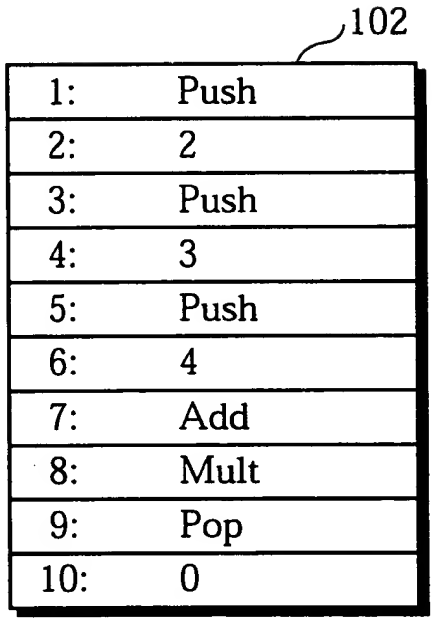

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FIG. 37

108

| 108a OPCODE | 108b NEXT INSTRUCTION INFORMATION | 108c JUMP ADDRESS | 108d NUMBER OF OPERANDS |
|---|---|---|---|
| : | : | : | : |
| Push | U | <JUMP ADDRESS OF CODE TO PERFORM Push ASSIGNED "U"> | 1 |
| Push | D | <JUMP ADDRESS OF CODE TO PERFORM Push ASSIGNED "D"> | 1 |
| Pop | U | <JUMP ADDRESS OF CODE TO PERFORM Pop ASSIGNED "U"> | 1 |
| Pop | D | <JUMP ADDRESS OF CODE TO PERFORM Pop ASSIGNED "D"> | 1 |
| Add | U | <JUMP ADDRESS OF CODE TO PERFORM Add ASSIGNED "U"> | 0 |
| Add | D | <JUMP ADDRESS OF CODE TO PERFORM Add ASSIGNED "D"> | 0 |
| Sub | U | <JUMP ADDRESS OF CODE TO PERFORM Sub ASSIGNED "U"> | 0 |
| Sub | D | <JUMP ADDRESS OF CODE TO PERFORM Sub ASSIGNED "D"> | 0 |
| Inc | U | <JUMP ADDRESS OF CODE TO PERFORM Inc ASSIGNED "U"> | 0 |
| Inc | D | <JUMP ADDRESS OF CODE TO PERFORM Inc ASSIGNED "D"> | 0 |
| : | : | : | : |

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FIG. 38A

| MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Push" WITH "U" | | |
|---|---|---|
| 1:Load | r4,r0 | ;COPY VALUE OF TOS REGISTER (#0) INTO SOS REGISTER (#4) |
| 2:Load | r0,[r2] | ;READ OPERAND INTO TOS REGISTER |
| 3:Inc | r2 | ;INCREMENT VIRTUAL MACHINE PC BY ONE TO PREPARE FOR READING NEXT INSTRUCTION |
| 4:Inc | r3 | ;INCREMENT VIRTUAL MACHINE SP BY ONE |
| 5:Store | [r3],r4 | ;PLACE SOS REGISTER VALUE INTO STACK |
| 6:Load | r1,[r2] | ;READ VIRTUAL MACHINE INSTRUCTION (JUMP ADDRESS) INDICATED BY PC INTO REGISTER #1 |
| 7:Inc | r2 | ;INCREMENT VIRTUAL MACHINE PC BY ONE |
| 8:Jmp | r1 | ;JUMP UNCONDITIONALLY TO LOCATION INDICATED BY REGISTER #1 |

FIG. 38B

| MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Push" WITH "D" | | |
|---|---|---|
| 1:Load | r4,r0 | ;COPY VALUE OF TOS REGISTER (#0) INTO SOS REGISTER (#4) |
| 2:Load | r0,[r2] | ;READ OPERAND INTO TOS REGISTER |
| 3:Inc | r2 | ;INCREMENT VIRTUAL MACHINE PC BY ONE TO PREPARE FOR READING NEXT INSTRUCTION |
| 6:Load | r1,[r2] | ;READ VIRTUAL MACHINE INSTRUCTION (JUMP ADDRESS) INDICATED BY PC INTO REGISTER #1 |
| 7:Inc | r2 | ;INCREMENT VIRTUAL MACHINE PC BY ONE |
| 8:Jmp | r1 | ;JUMP UNCONDITIONALLY TO LOCATION INDICATED BY REGISTER #1 |

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FIG. 39A

| MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Add" WITH "U" |
| --- |
| 1:Add r0,r0,r4 ;ADD VALUES OF TOS REGISTER AND SOS REGISTER, AND PLACE RESULT INTO TOS REGISTER<br><br><MICROPROGRAM FOR VIRTUAL MACHINE JUMP CODE WITH "U"> |

FIG. 39B

| MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Add" WITH "D" |
| --- |
| 1:Add r0,r0,r4 ;ADD VALUES OF TOS REGISTER AND SOS REGISTER, AND PLACE RESULT INTO TOS REGISTER<br><br><MICROPROGRAM FOR VIRTUAL MACHINE JUMP CODE WITH "D"> |

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FIG. 40A

| MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Mult" WITH "U" |
| --- |
| 1:Mult r0,r0,r4 ;MULTIPLY VALUES OF TOS REGISTER AND SOS REGISTER, AND PLACE RESULT INTO TOS REGISTER<br><MICROPROGRAM FOR VIRTUAL MACHINE JUMP CODE WITH "U"> |

FIG. 40B

| MICROPROGRAM FOR VIRTUAL MACHINE INSTRUCTION "Mult" WITH "D" |
| --- |
| 1:Mult r0,r0,r4 ;MULTIPLY VALUES OF TOS REGISTER AND SOS REGISTER, AND PLACE RESULT INTO TOS REGISTER<br><MICROPROGRAM FOR VIRTUAL MACHINE JUMP CODE WITH "D"> |

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FIG. 41A

```
MICROPROGRAM FOR VIRTUAL MACHINE JUMP CODE WITH "U"
1:Load  r1,[r2]  ;READ VIRTUAL MACHINE INSTRUCTION
                  (JUMP ADDRESS) INDICATED BY VIRTUAL
                  MACHINE PC INTO REGISTER #1
2:Inc   r2       ;INCREMENT VALUE OF VIRTUAL MACHINE PC BY ONE
3:Jmp   r1       ;JUMP UNCONDITIONALLY TO LOCATION
                  INDICATED BY REGISTER #1
```

FIG. 41B

```
MICROPROGRAM FOR VIRTUAL MACHINE JUMP CODE WITH "D"
1:Load  r1,[r2]  ;READ VIRTUAL MACHINE INSTRUCTION
                  (JUMP ADDRESS) INDICATED BY VIRTUAL
                  MACHINE PC INTO REGISTER #1
2:Load  r4,[r3]  ;READ VALUE FROM STACK AND COPY IT
                  INTO SOS REGISTER
3:Inc   r2       ;INCREMENT VALUE OF VIRTUAL MACHINE PC BY ONE
4:Dec   r3       ;DECREMENT VALUE OF VIRTUAL MACHINE SP BY ONE
5:Jmp   r1       ;JUMP UNCONDITIONALLY TO LOCATION
                  INDICATED BY REGISTER #1
```

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FIG. 42

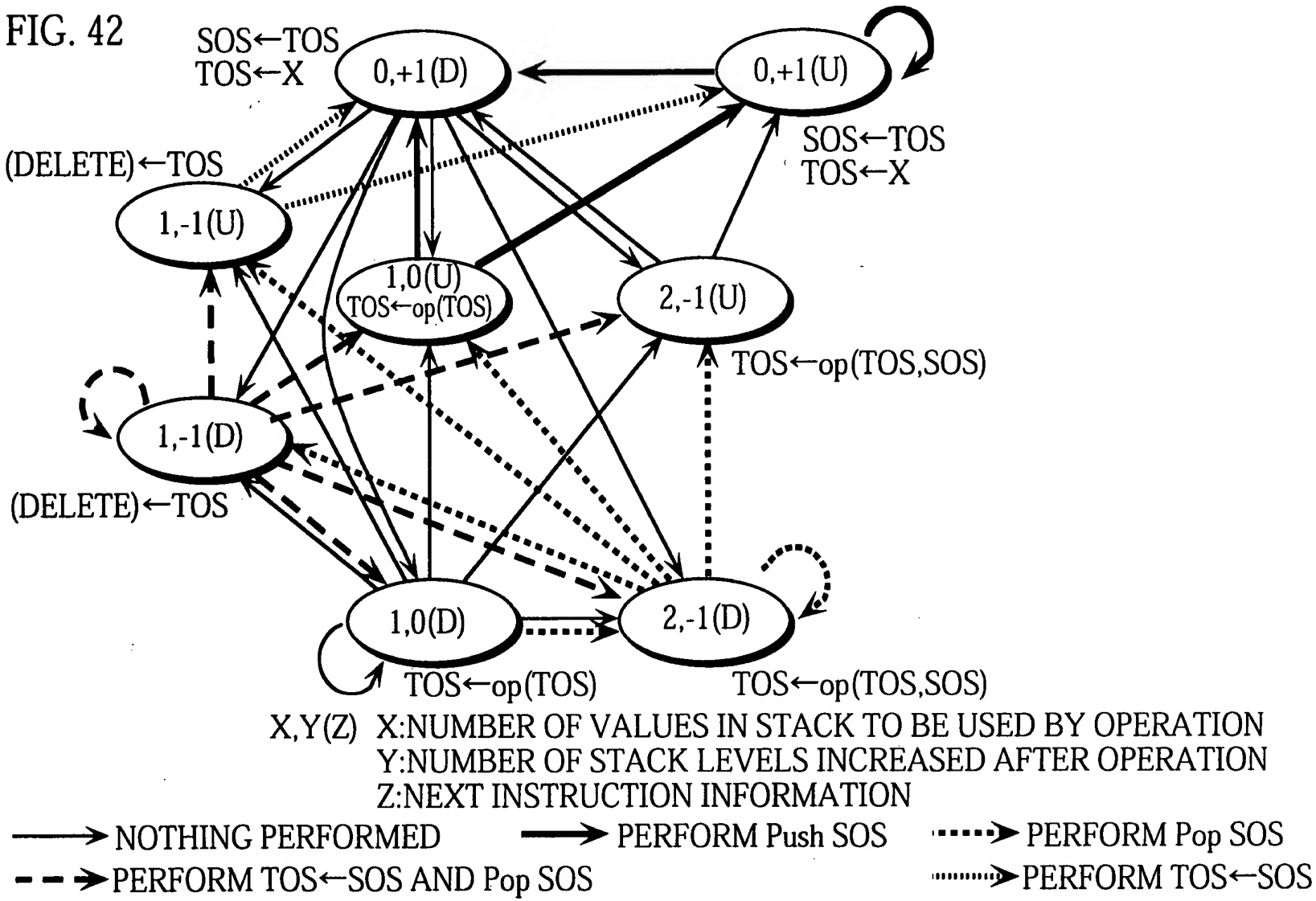

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FIG. 43

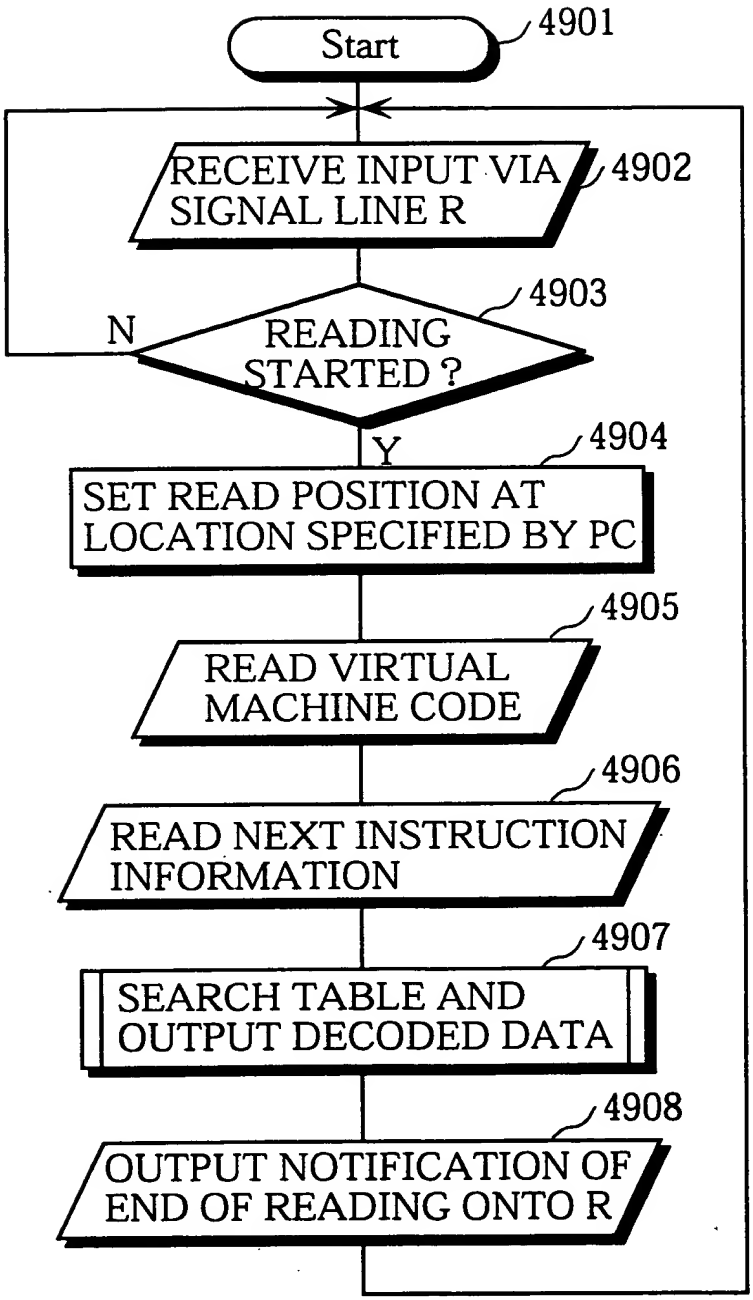

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FIG. 44

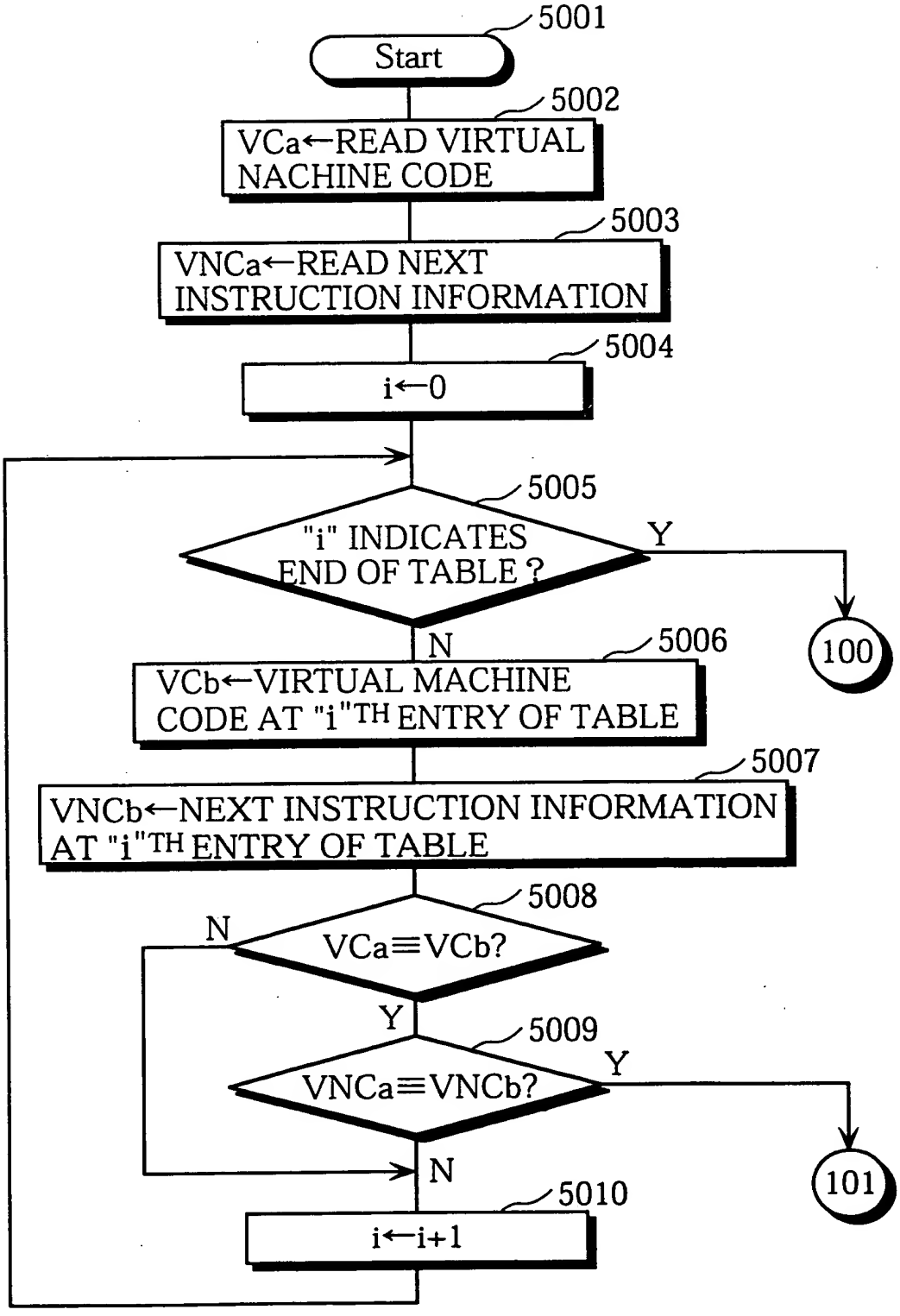

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FIG. 45

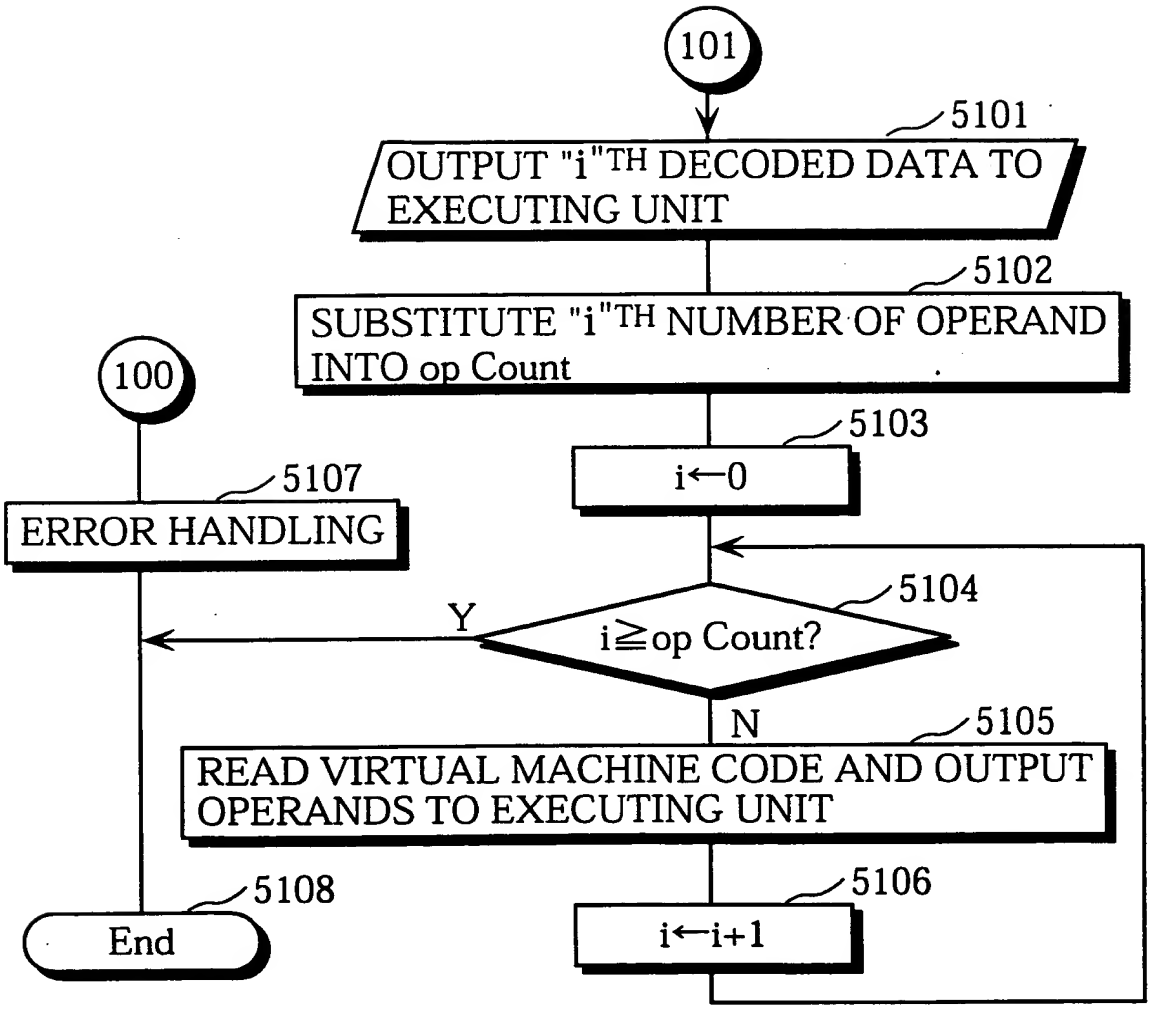

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FIG. 46

| |
|---|
| 1:<JUMP ADDRESS OF CODE TO PERFORM Push WITH "U"> |
| 2:OPERAND "2" |
| 3:<JUMP ADDRESS OF CODE TO PERFORM Push WITH "U"> |
| 4:OPERAND "3" |
| 5:<JUMP ADDRESS OF CODE TO PERFORM Push WITH "D"> |
| 6:OPERAND "4" |
| 7:<JUMP ADDRESS OF CODE TO PERFORM Add WITH "D"> |
| 8:<JUMP ADDRESS OF CODE TO PERFORM Mult WITH "D"> |
| 9:<JUMP ADDRESS OF CODE TO PERFORM Pop WITH "U"> |
| 10:OPERAND "0" |

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FIG. 47A

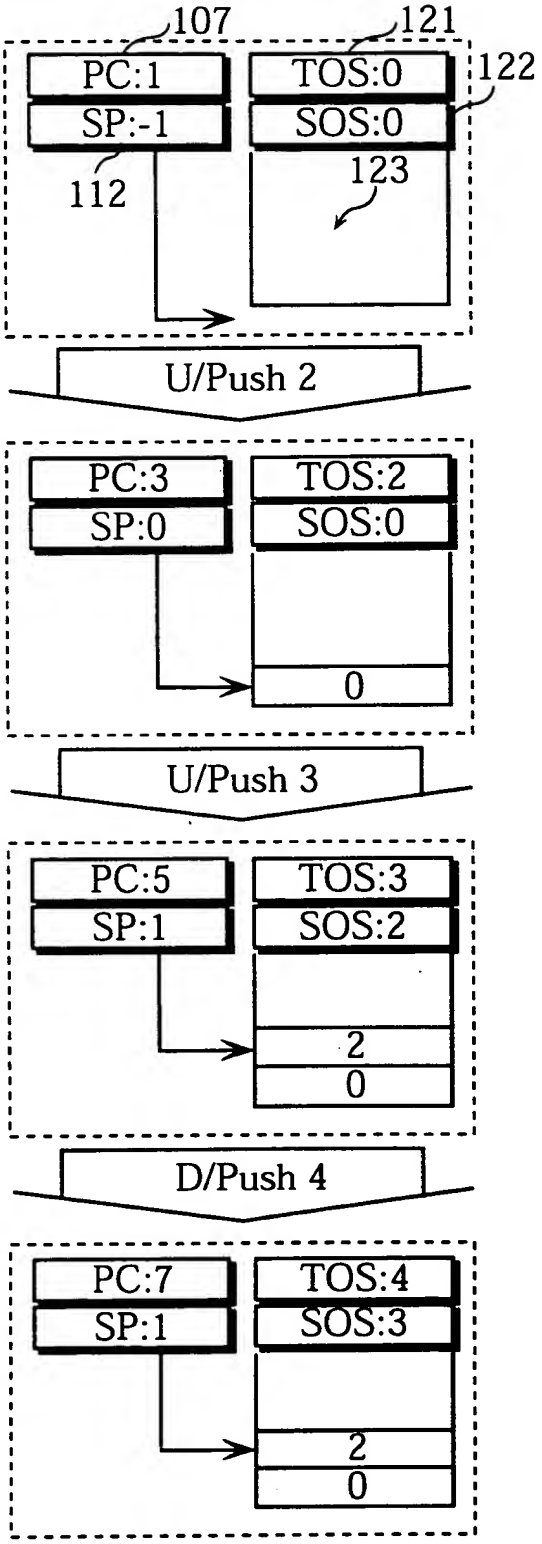


FIG. 47B

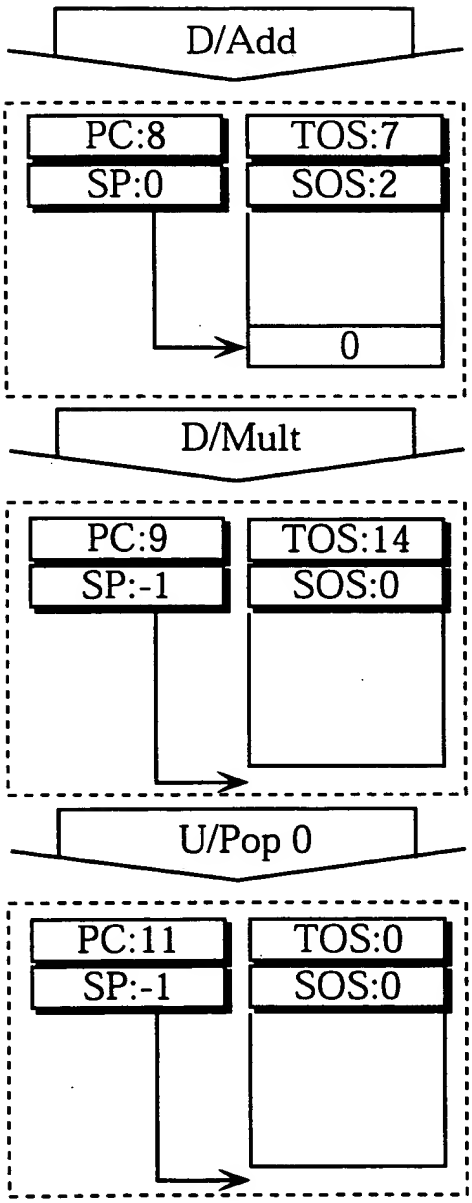

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FIG. 48

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | | |
| Load r4,[r3] | | IF | RF | ALU | MEM | WB | | | | | |
| Inc r2 | | | IF | RF | ALU | MEM | WB | | | | |
| Dec r3 | | | | IF | RF | ALU | MEM | WB | | | |
| Jmp r1 | | | | | IF | RF | ALU | MEM | WB | | |
| | | | | | | IF | x | | | | |
| Mult r0,r0,r4 | | | | | | | IF | RF | ALU | MEM | WB |

FIG. 49

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | |
| Load r4,[r3] | IF | RF | ALU | MEM | WB | | | | |
| Inc r2 | | IF | RF | ALU | MEM | WB | | | |
| Dec r3 | | IF | RF | ALU | MEM | WB | | | |
| Jmp r1 | | | IF | RF | ALU | MEM | WB | | |
| | | | IF | RF | x | | | | |
| | | | | IF | x | | | | |
| | | | | IF | x | | | | |
| Mult r0,r0,r4 | | | | | IF | RF | ALU | MEM | WB |

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FIG. 50

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | | |
| Load r4,[r3] | | IF | RF | ALU | MEM | WB | | | | | |
| Inc r2 | | | IF | RF | ALU | MEM | WB | | | | |
| Dec r3 | | | | IF | RF | ALU | MEM | WB | | | |
| Jmp r1 | | | | | IF | RF | ALU | MEM | WB | | |
| | | | | | | IF | x | | | | |
| Mult r0,r0,r4 | | | | | | | IF | RF | ALU | MEM | WB |

FIG. 51

| CLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Load r1,[r2] | IF | RF | ALU | MEM | WB | | | | | |
| Load r4,[r3] | IF | RF | ALU | MEM | WB | | | | | |
| Inc r2 | | IF | RF | ALU | MEM | WB | | | | |
| Dec r3 | | IF | RF | ALU | MEM | WB | | | | |
| Jmp r1 | | | IF | RF | • | ALU | MEM | WB | | |
| | | | IF | RF | ALU | x | | | | |
| | | | | IF | RF | x | | | | |
| | | | | IF | RF | x | | | | |
| | | | | | IF | x | | | | |
| | | | | | IF | x | | | | |
| Mult r0,r0,r4 | | | | | | IF | RF | ALU | MEM | WB |

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FIG. 52

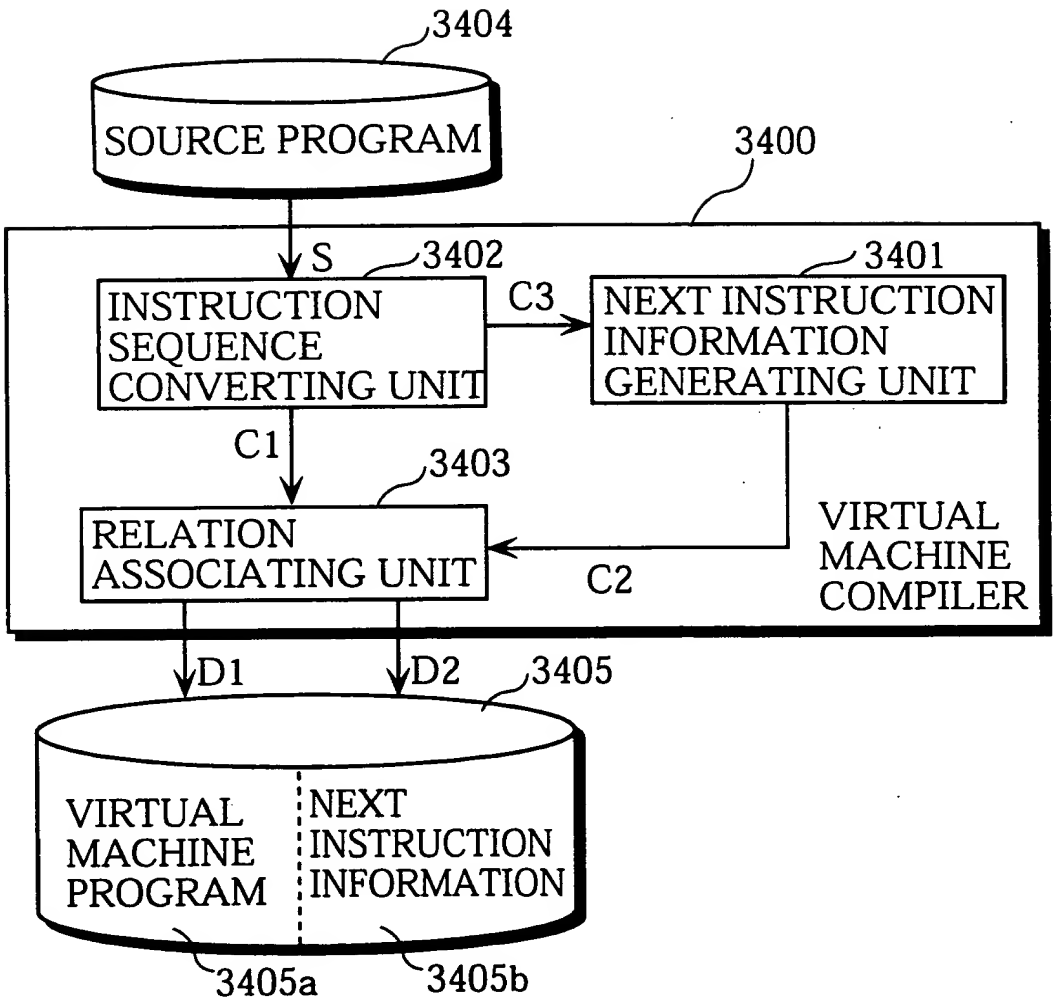

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FIG. 53

DATA CONSTRUCTION OF
INSTRUCTION SEQUENCE:"x=(1+2)*(3+4)"

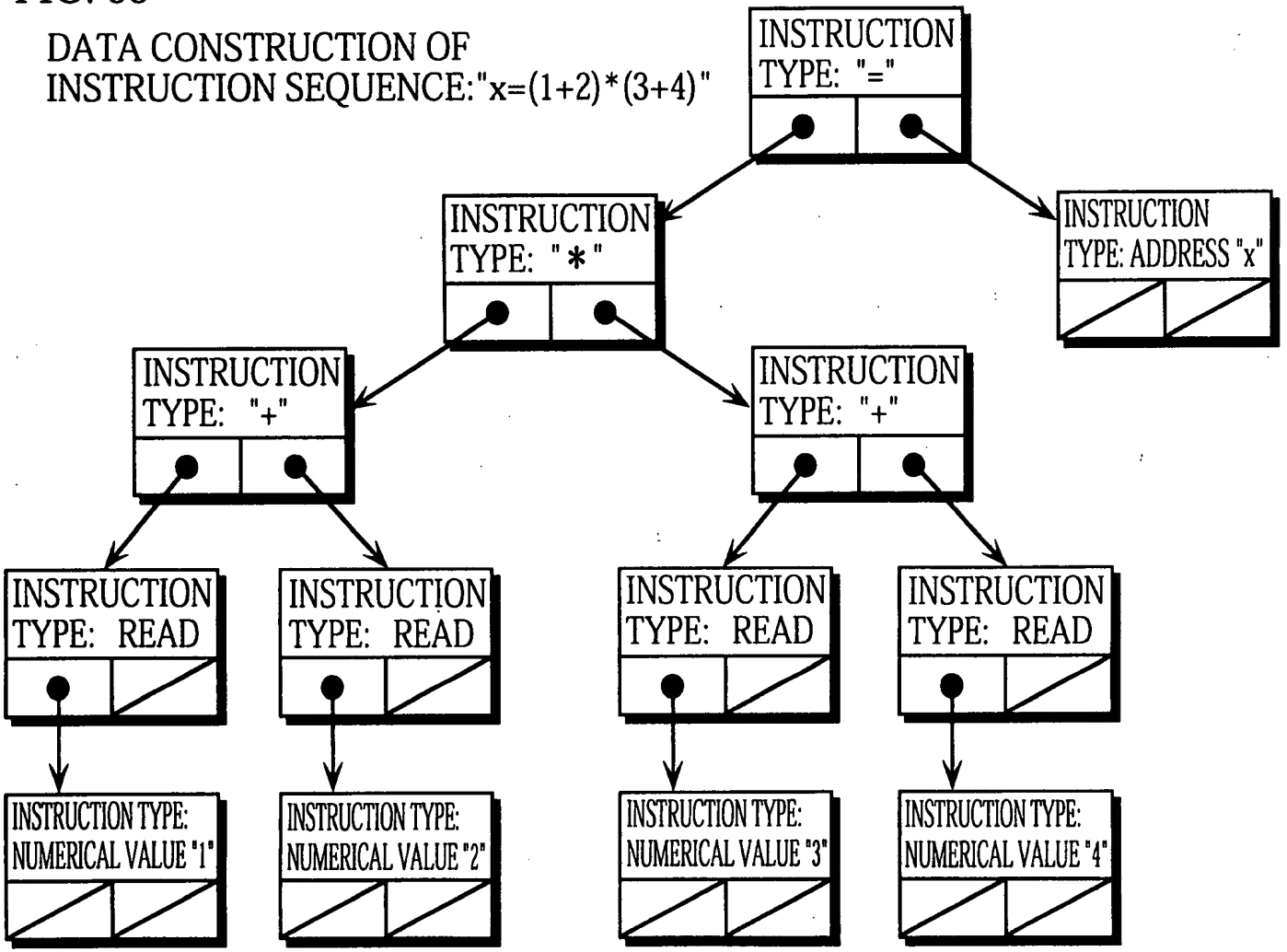

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FIG. 54

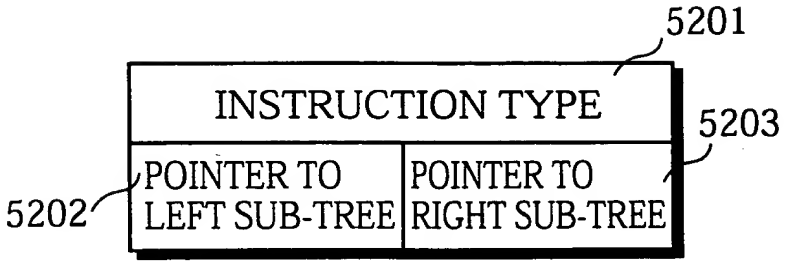


FIG. 55

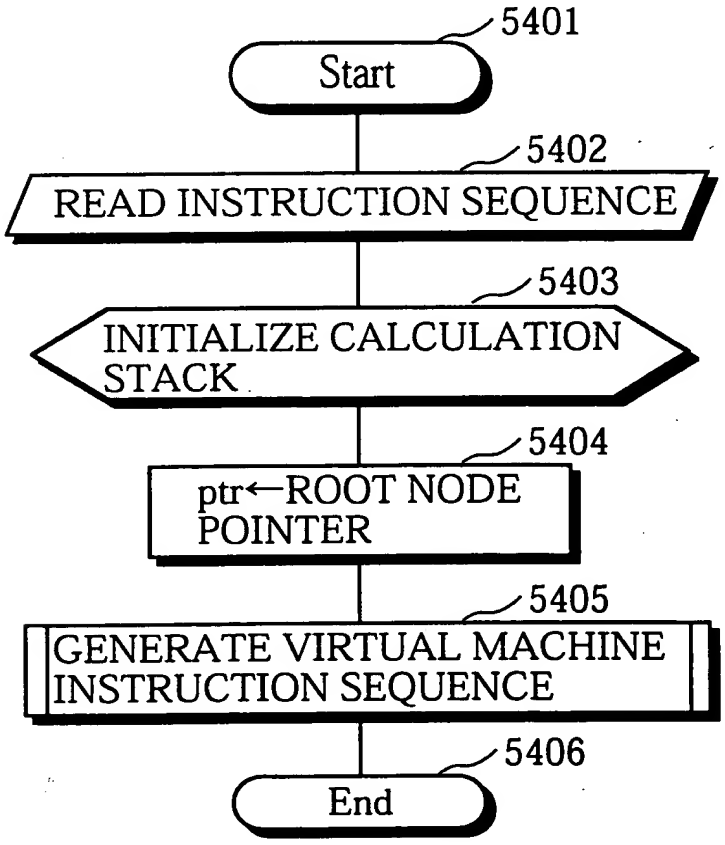

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FIG. 56

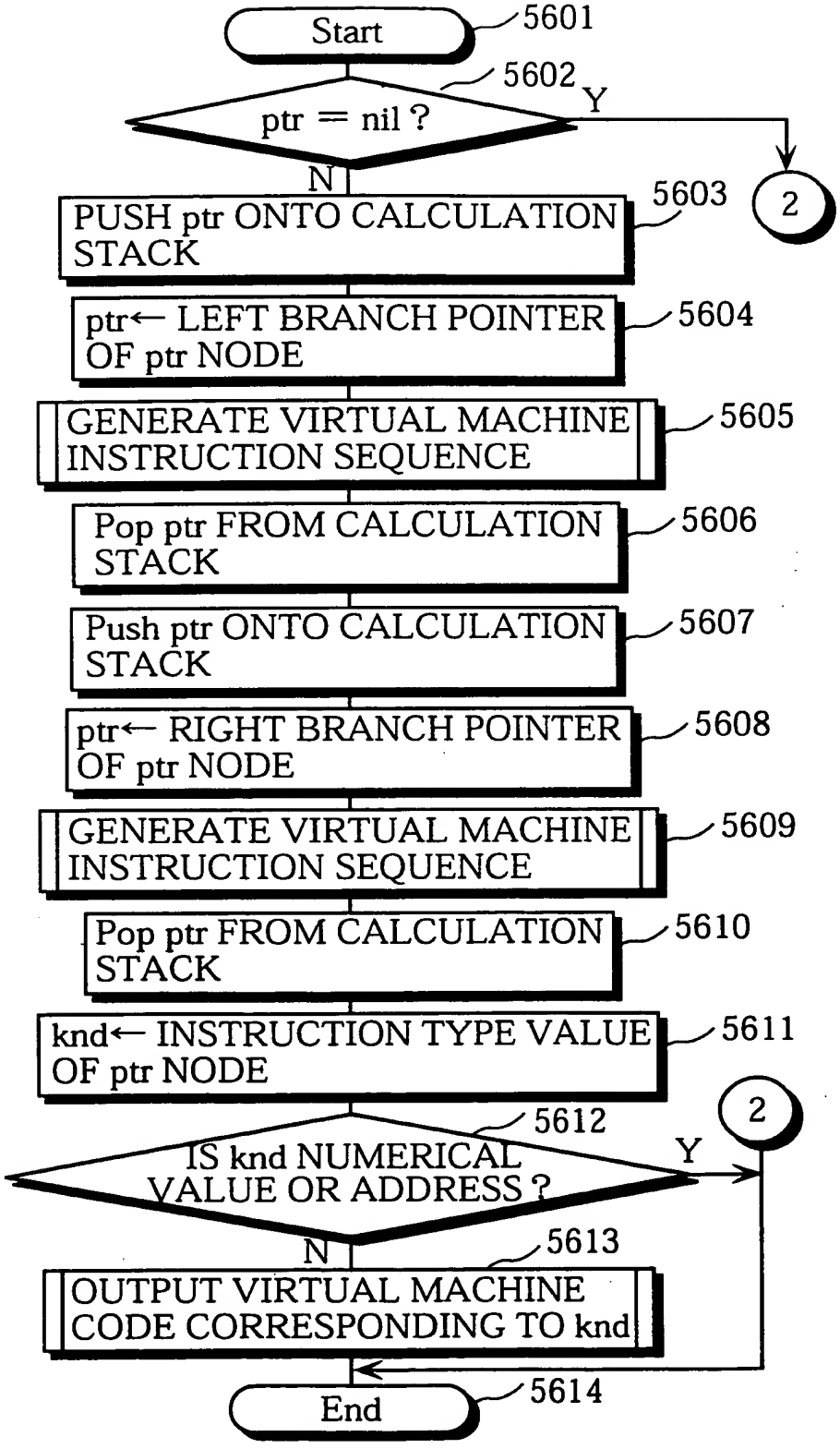

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FIG. 57A

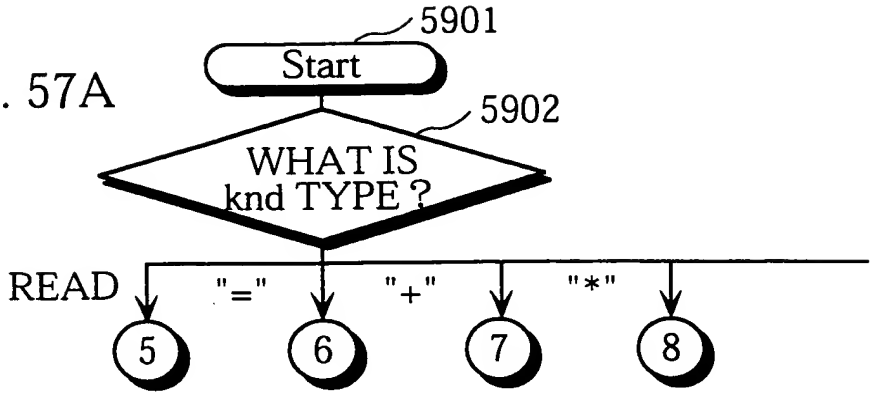


FIG. 57B

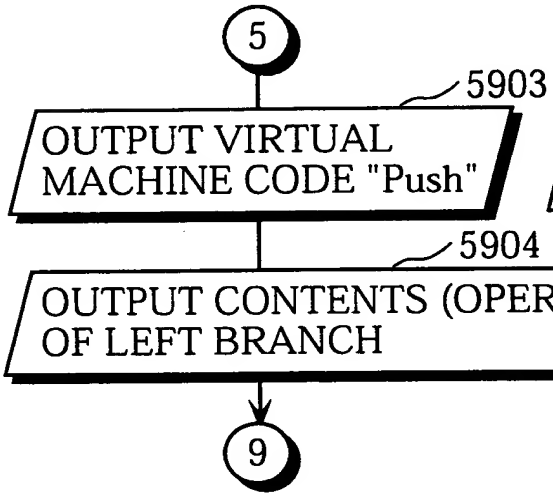


FIG. 57C

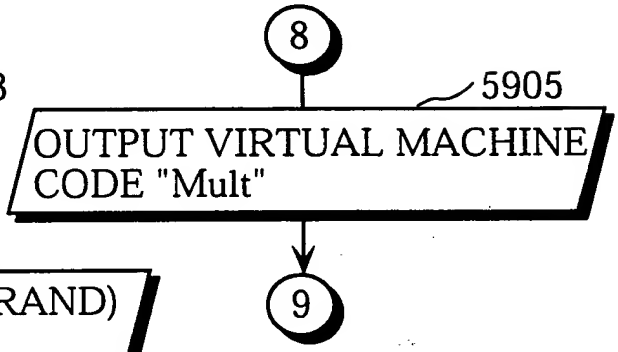


FIG. 57E

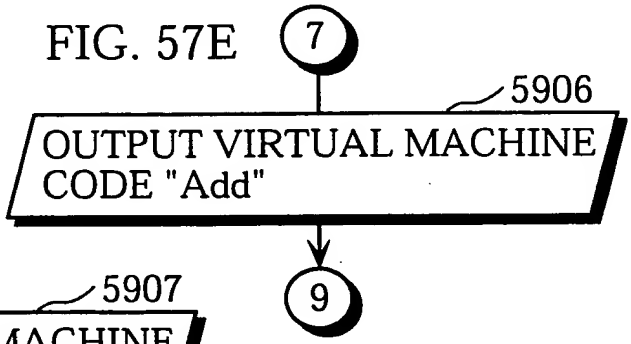


FIG. 57D

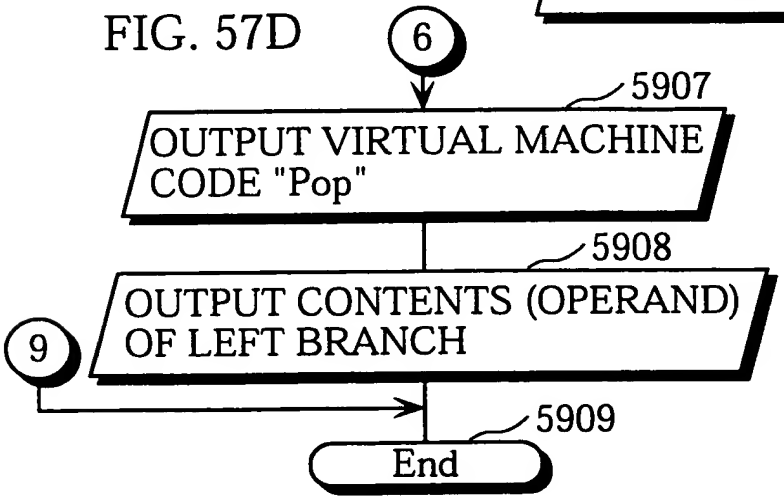

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FIG. 58

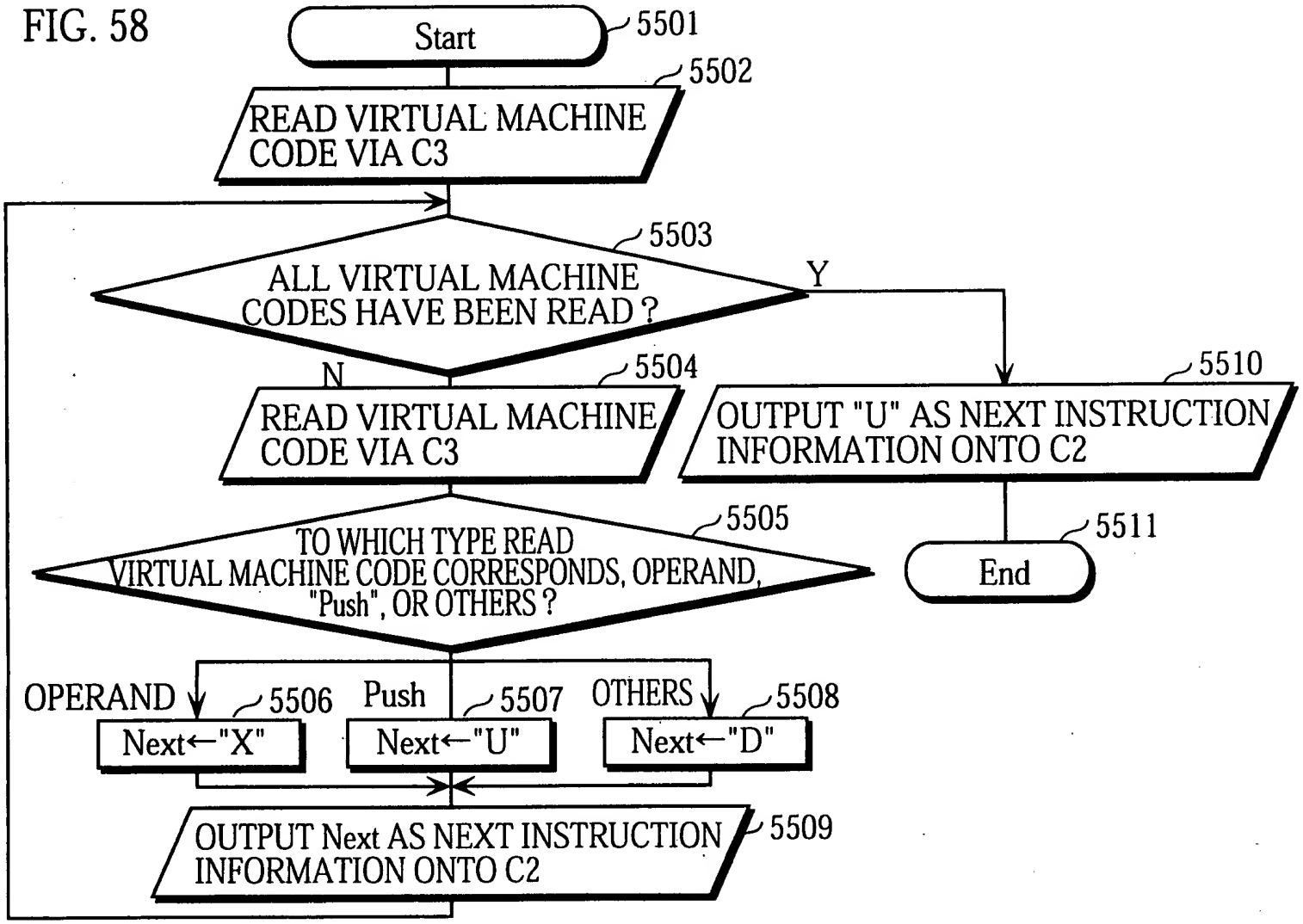

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FIG. 59

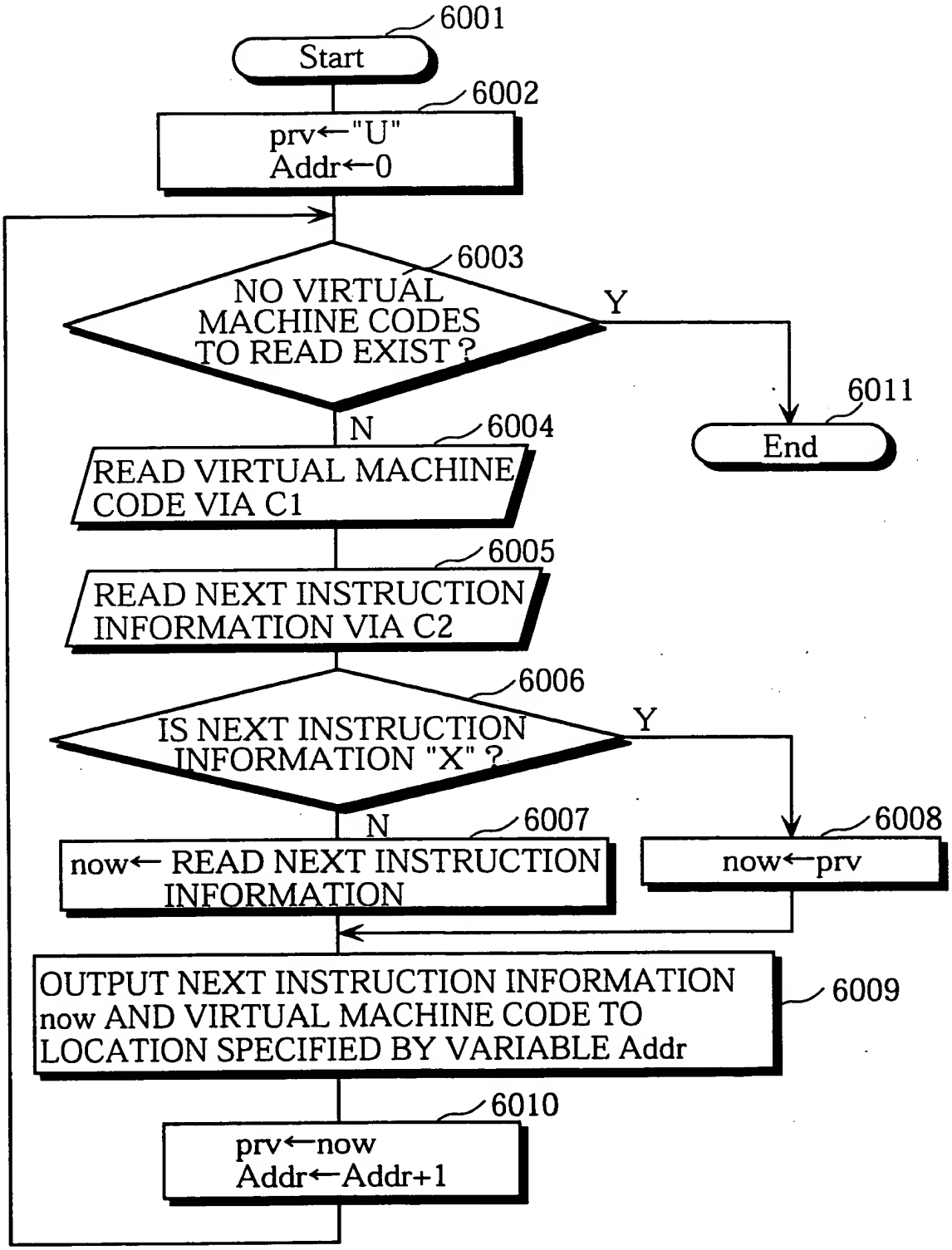

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FIG. 60

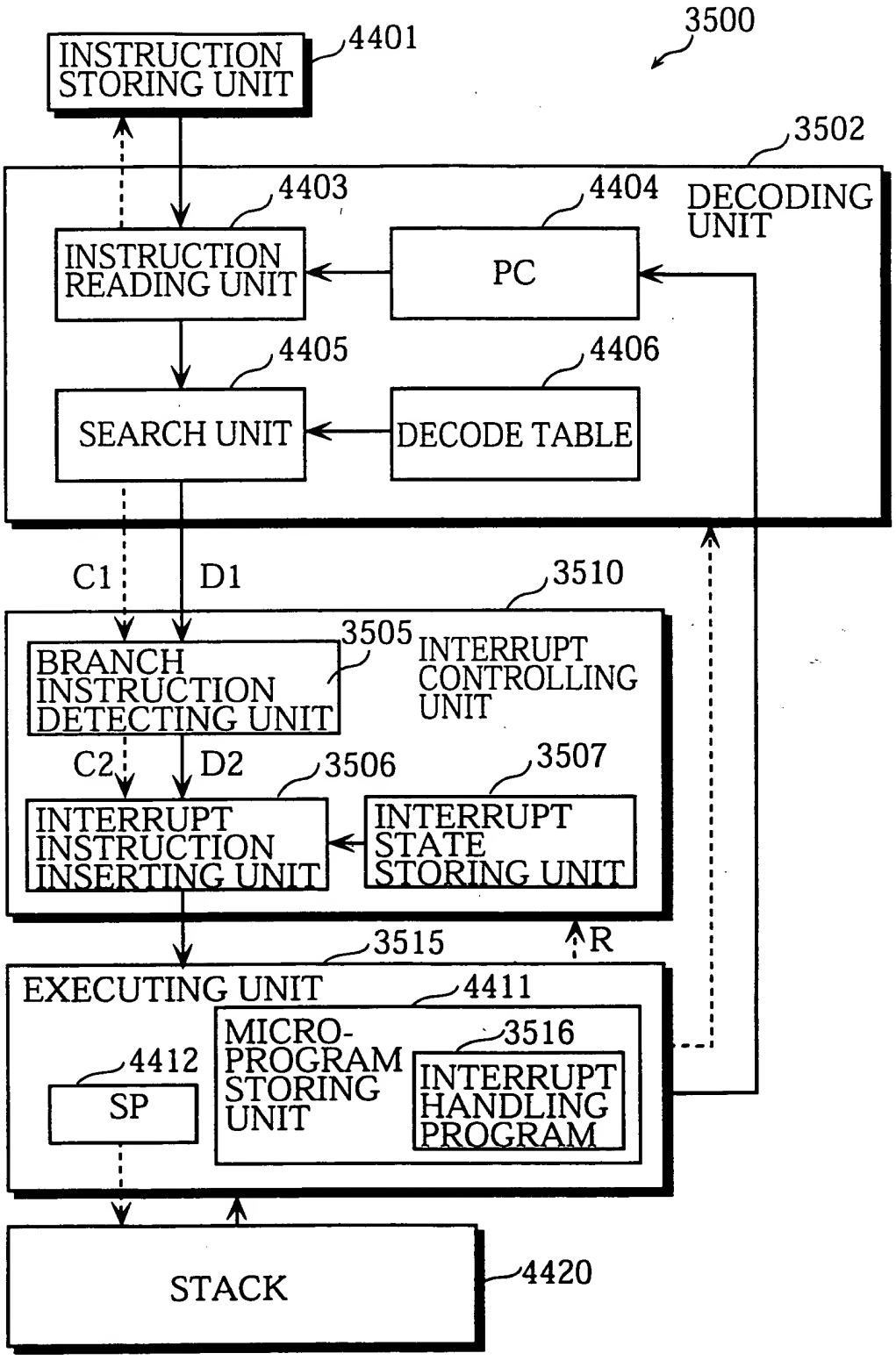

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FIG. 61

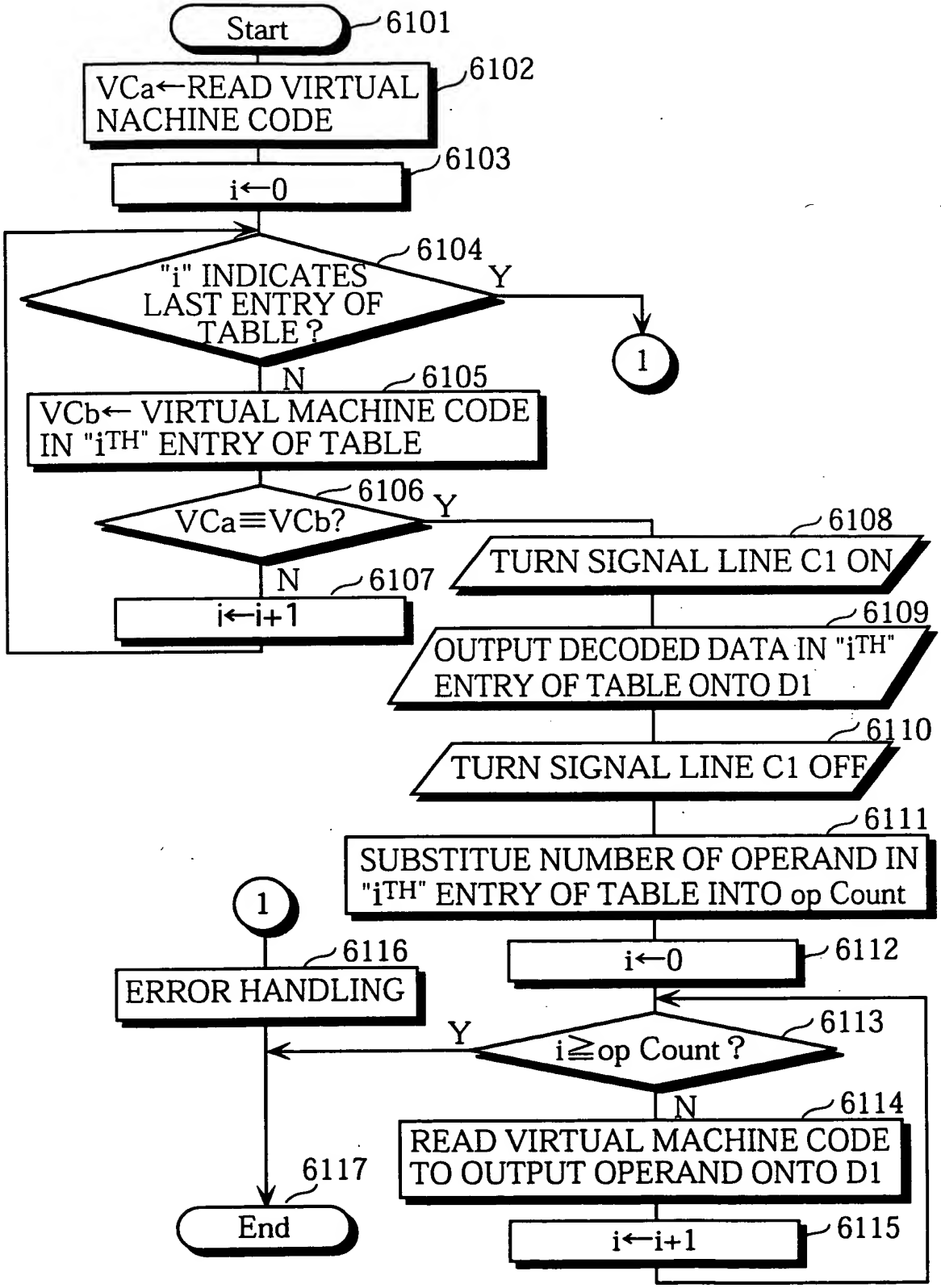

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FIG. 62

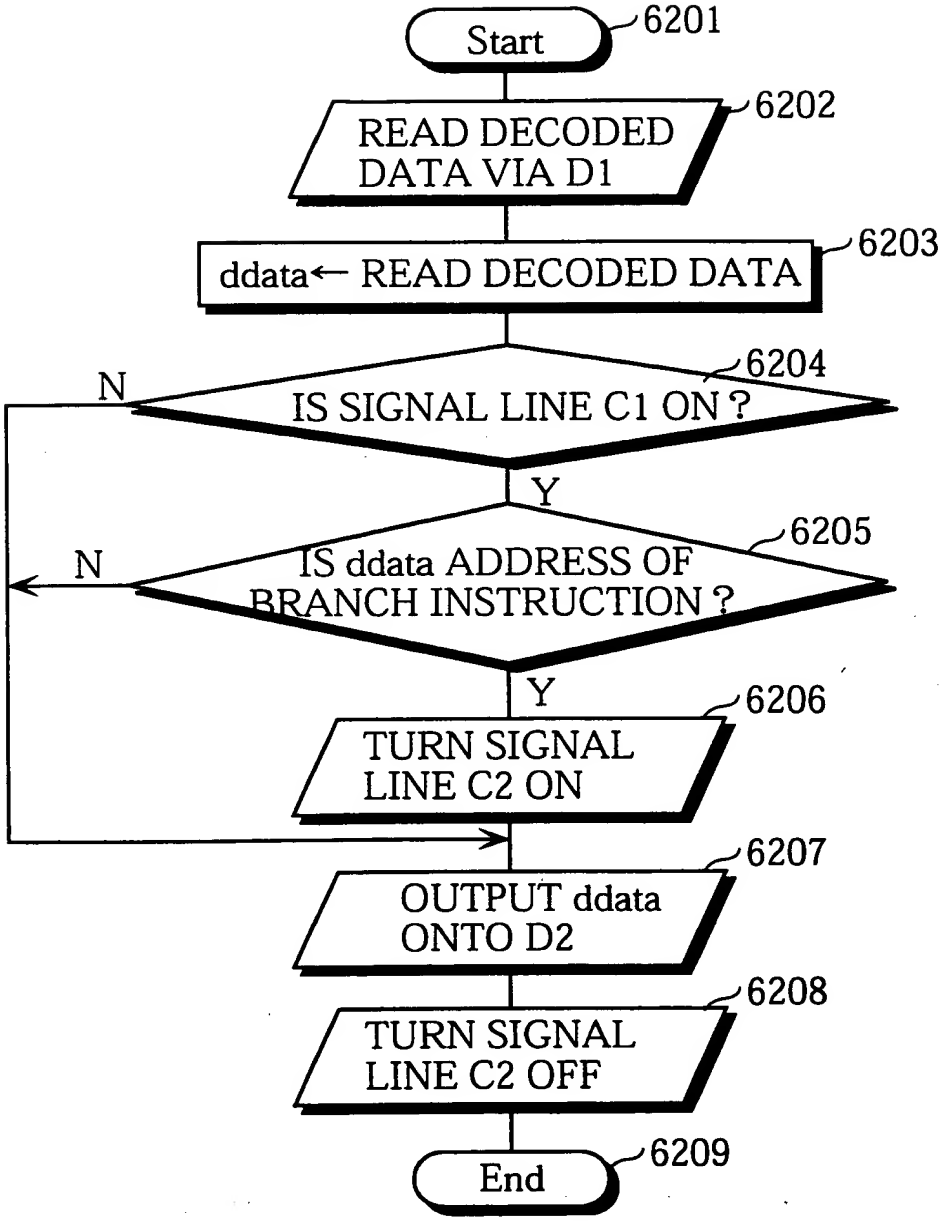

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FIG. 63

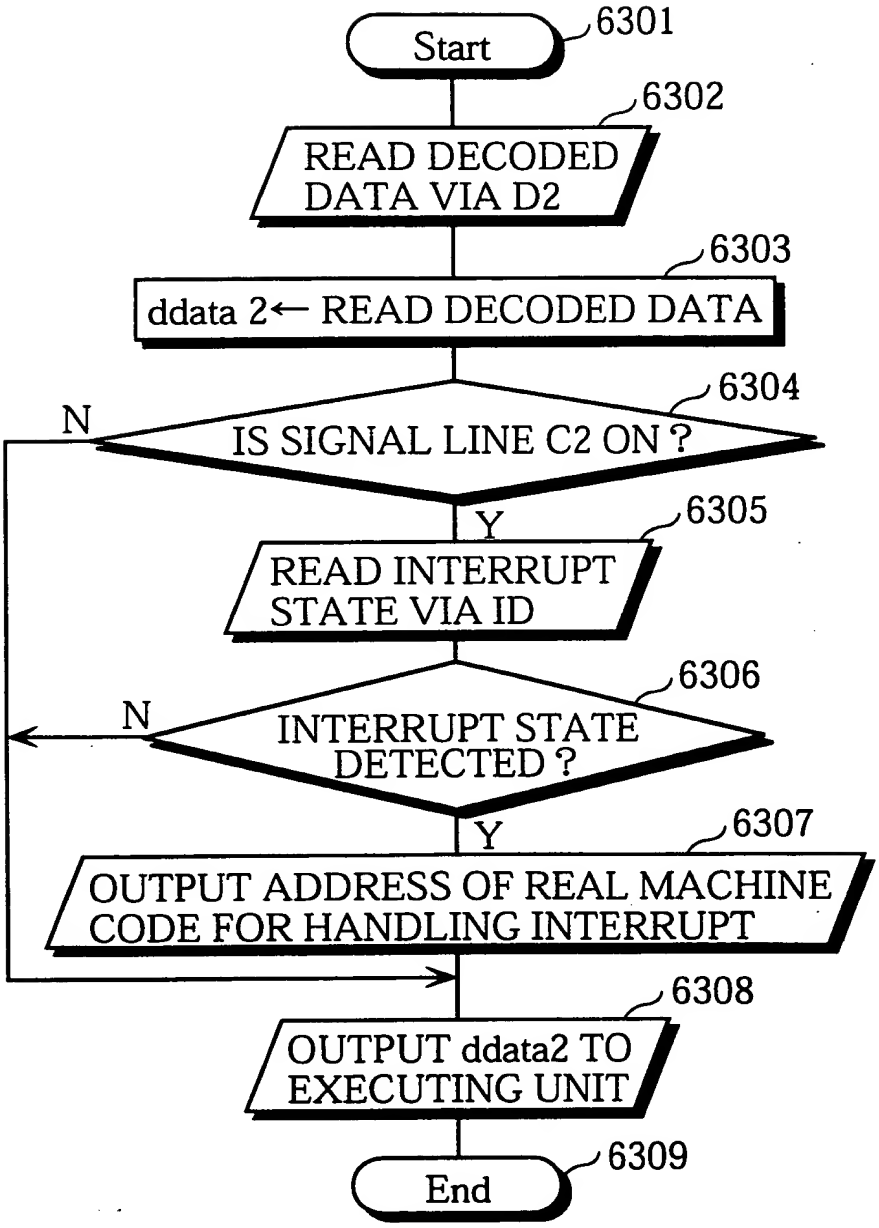

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FIG. 64

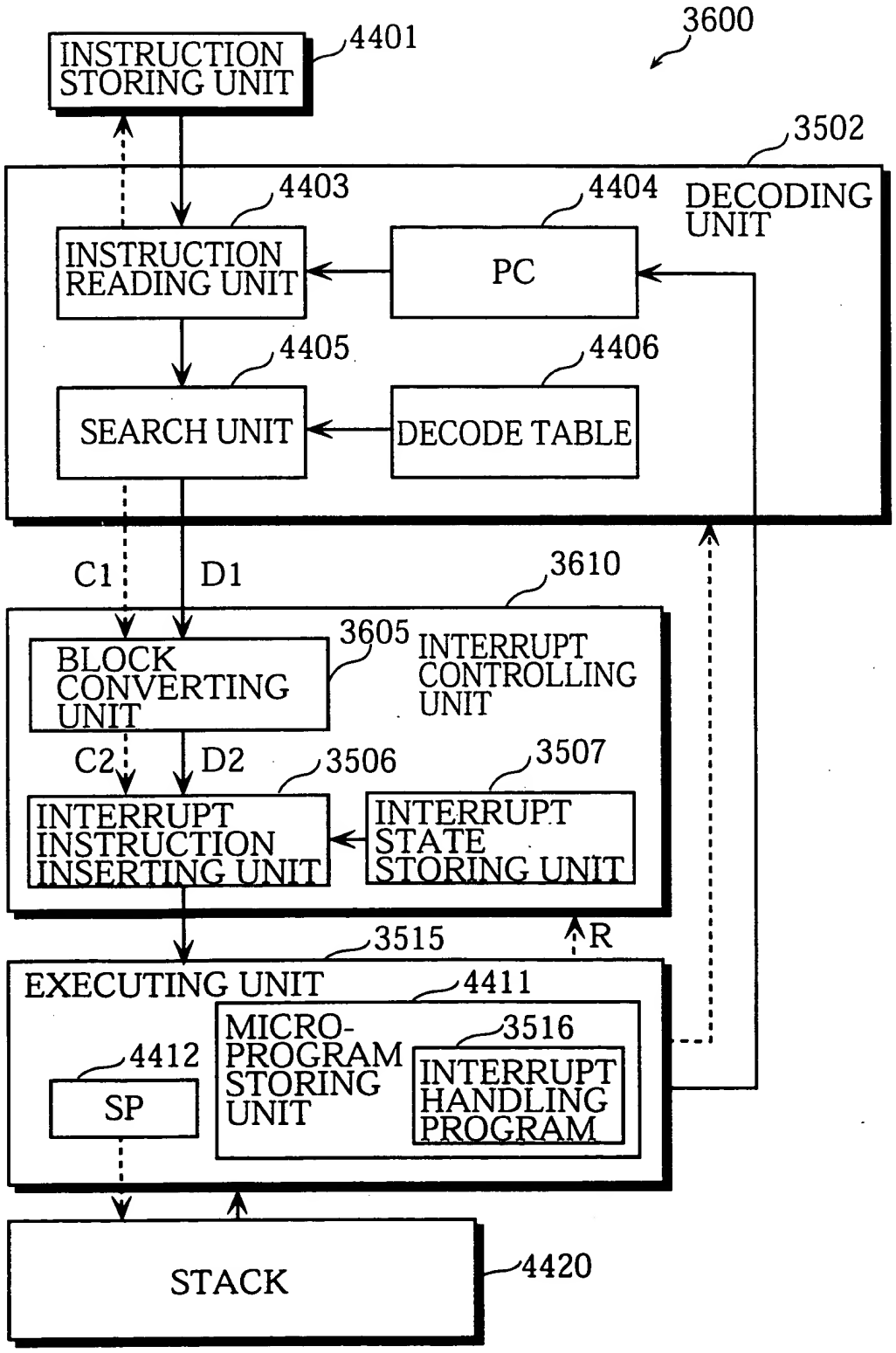

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FIG. 65

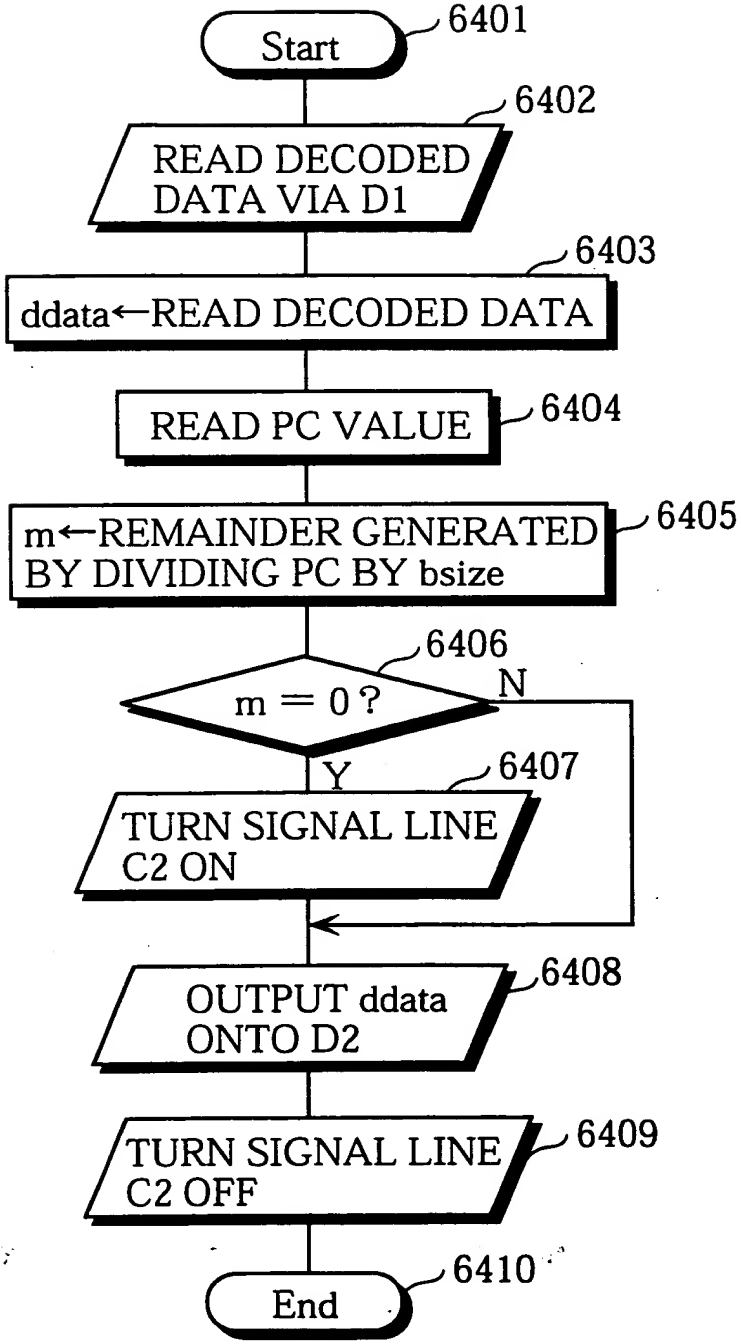

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FIG. 66

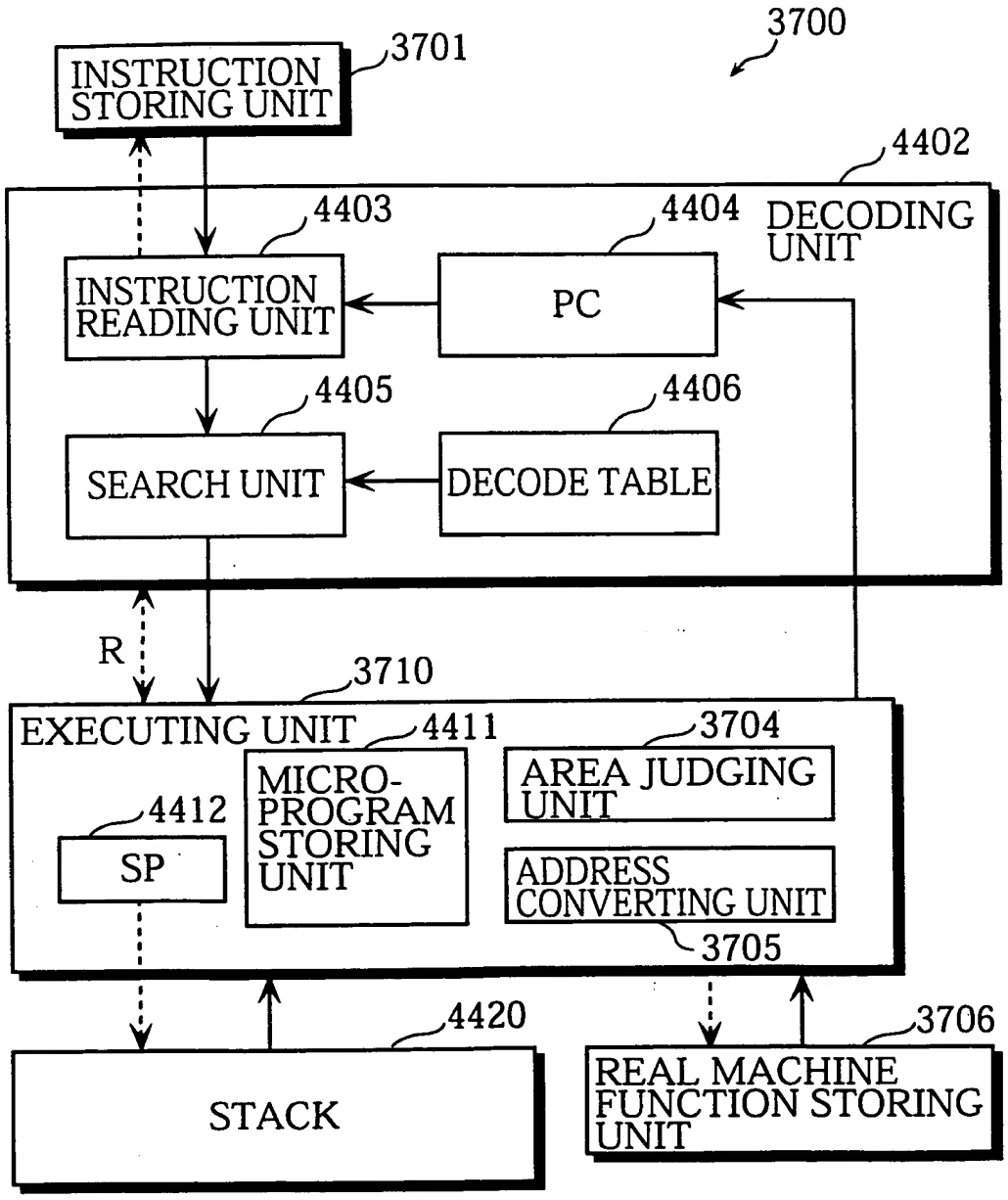

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FIG. 67

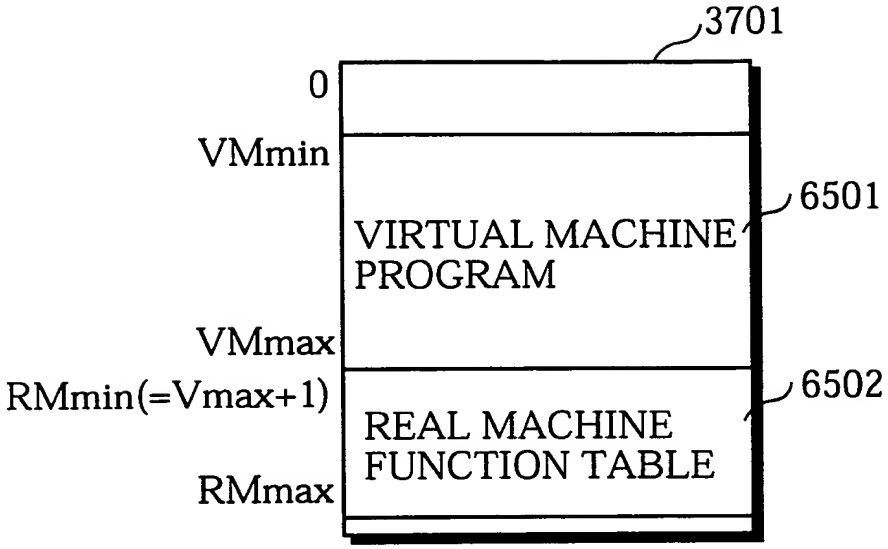


FIG. 68

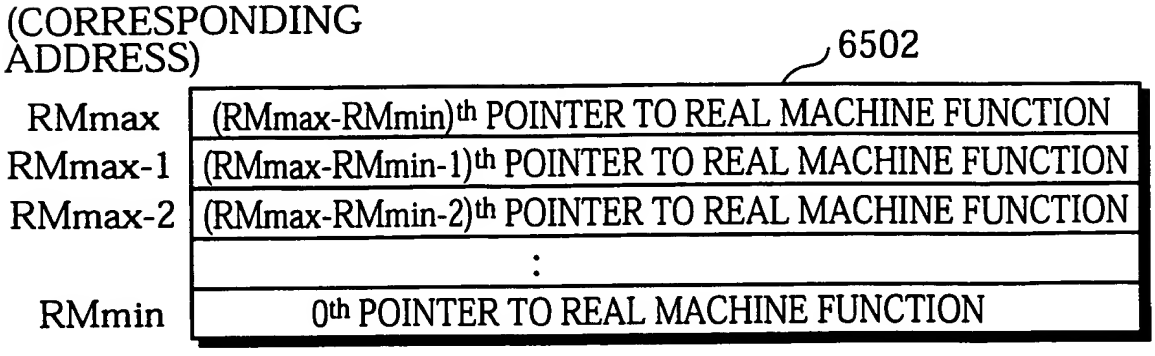

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FIG. 69

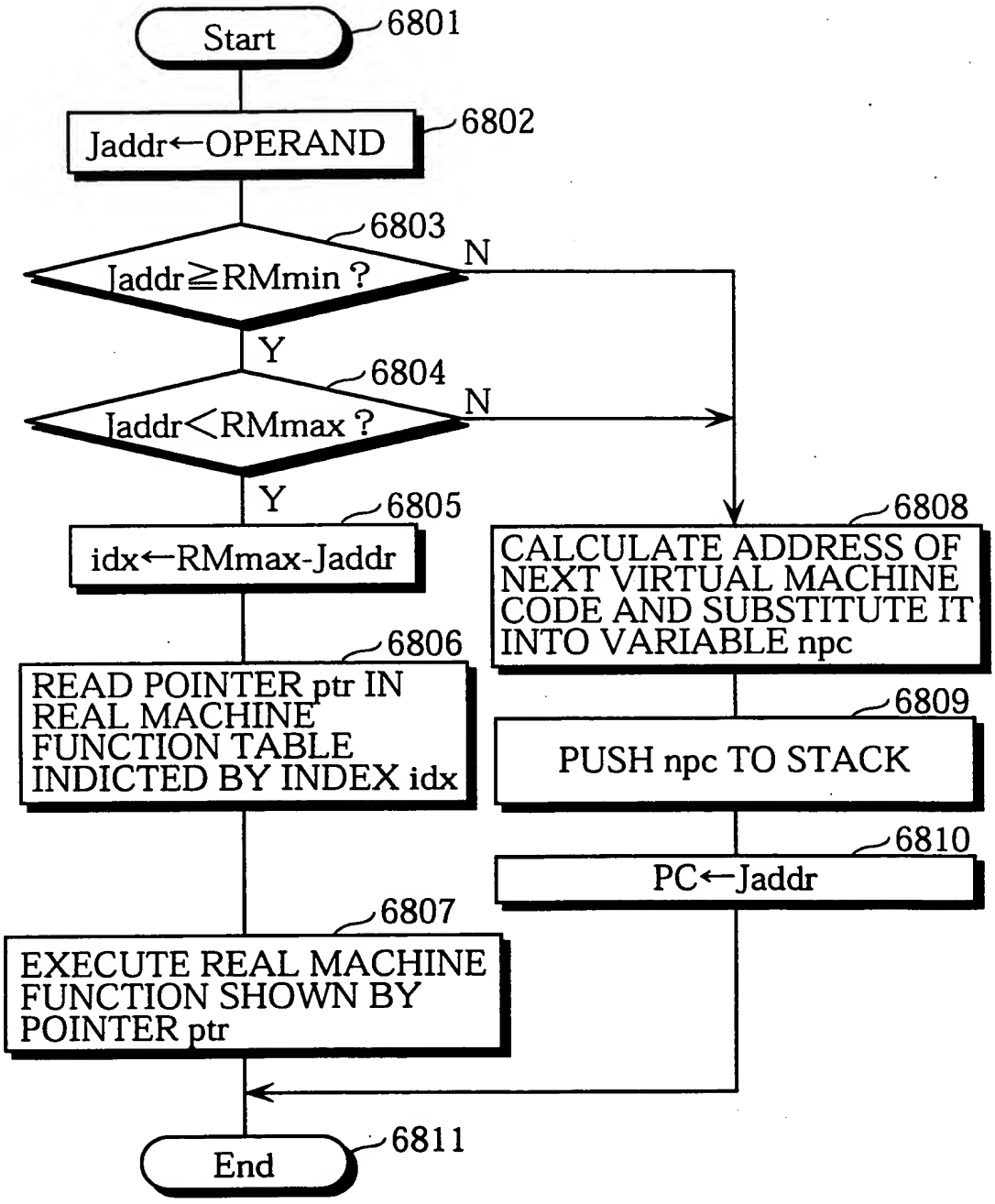

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FIG. 70

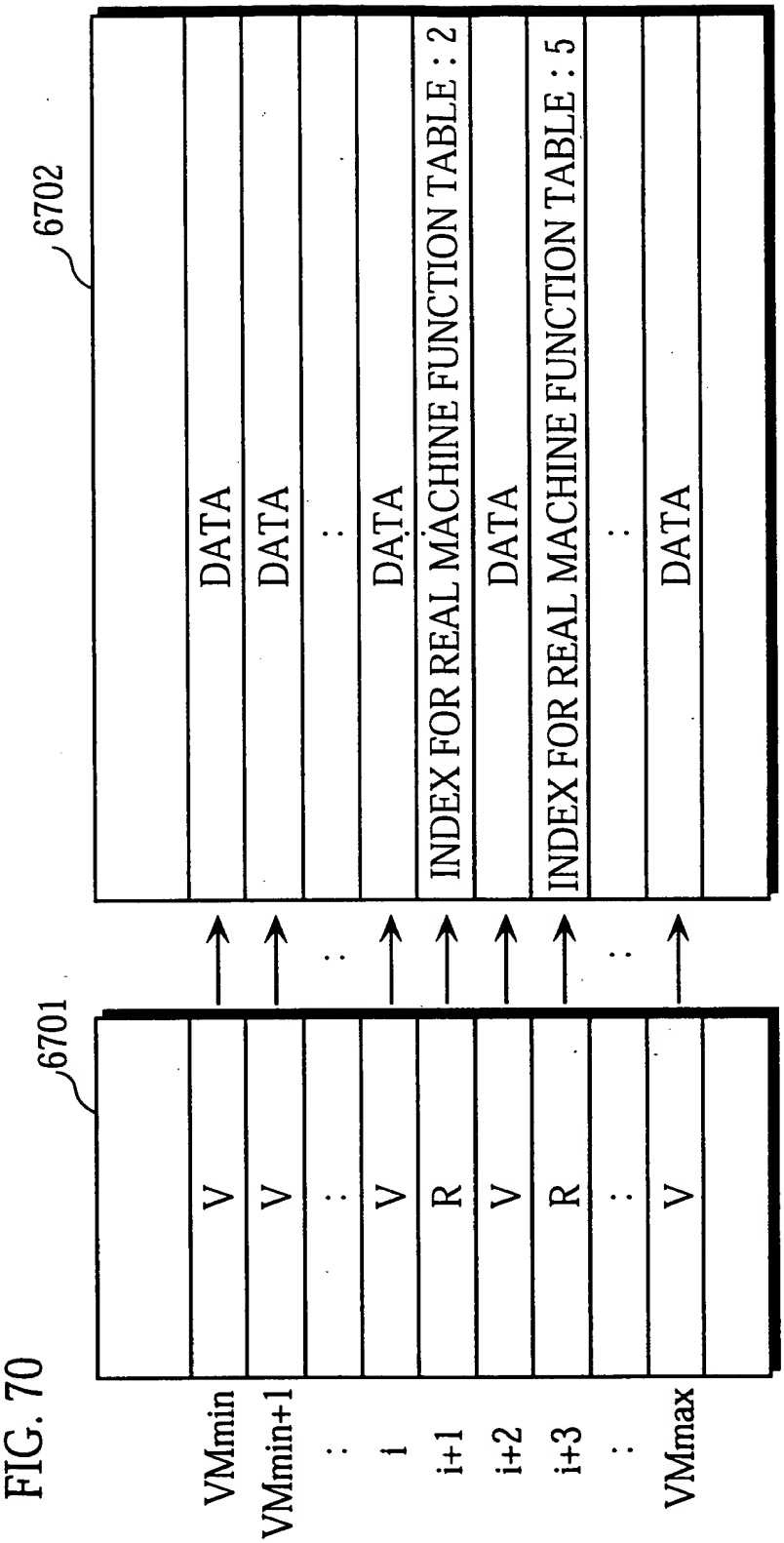

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FIG. 71

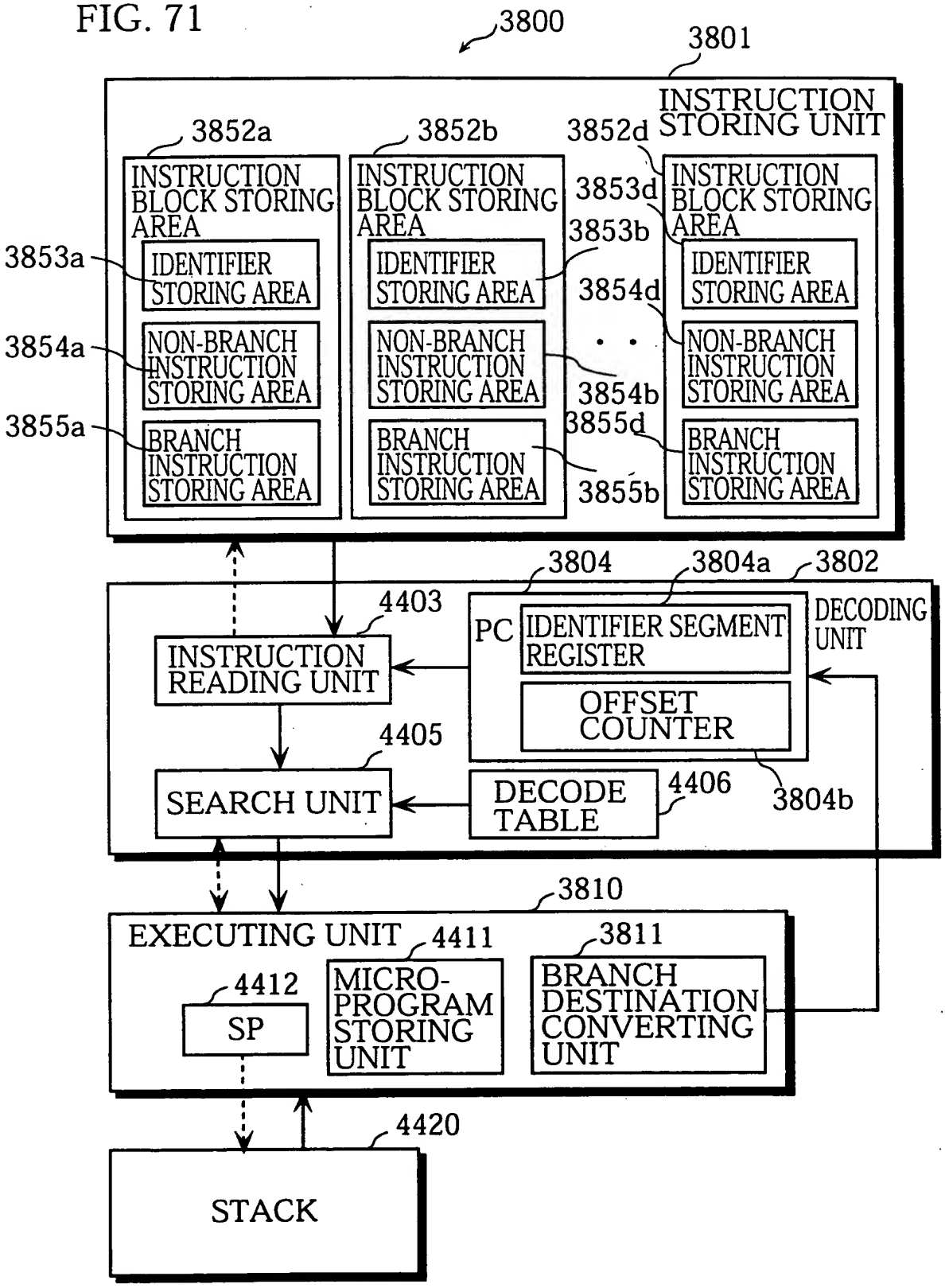

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FIG. 72

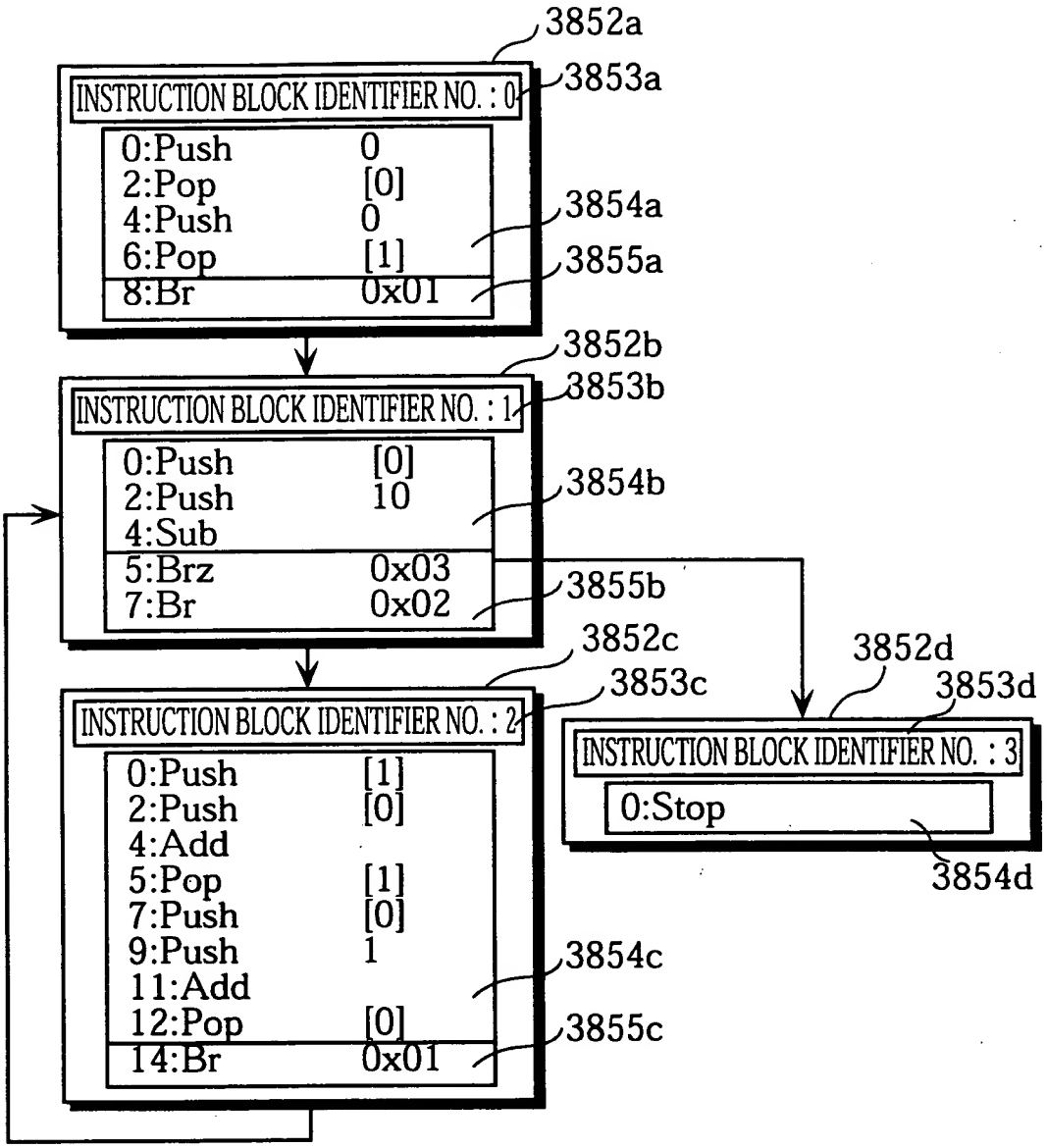

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FIG. 73

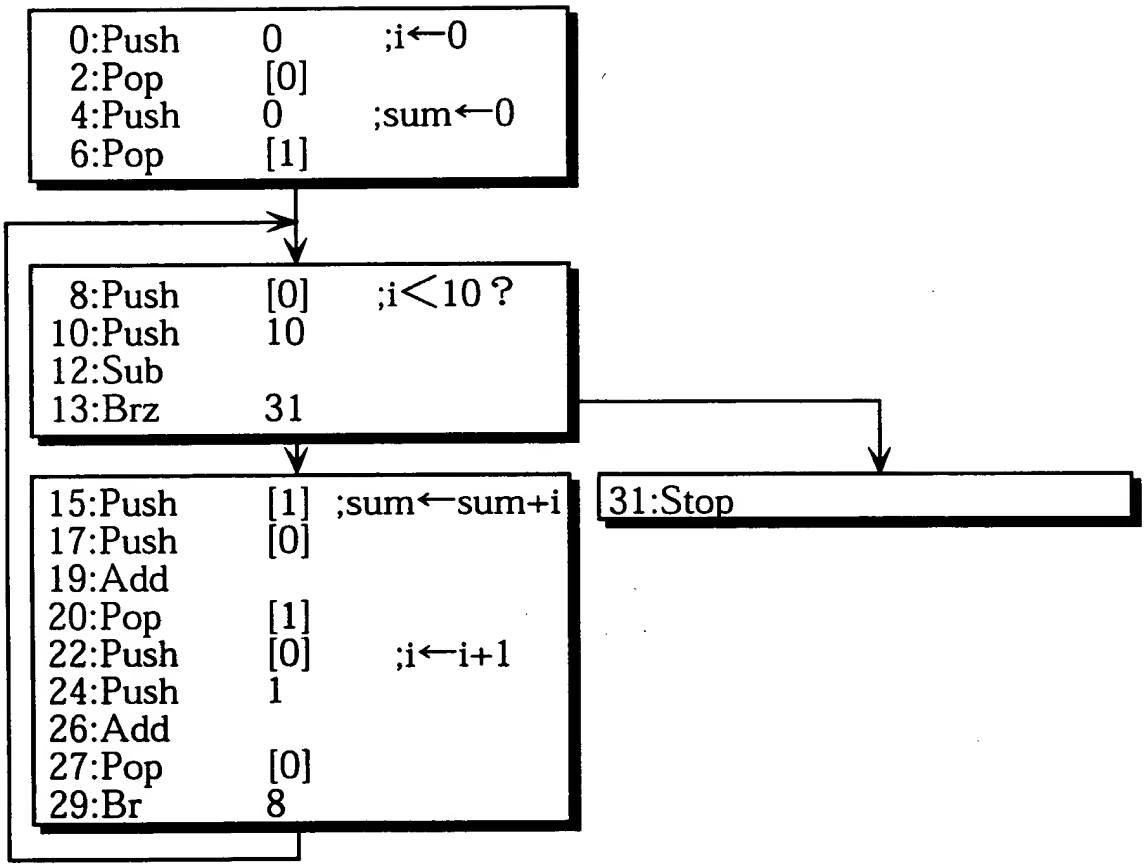

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FIG. 74


FIG. 75

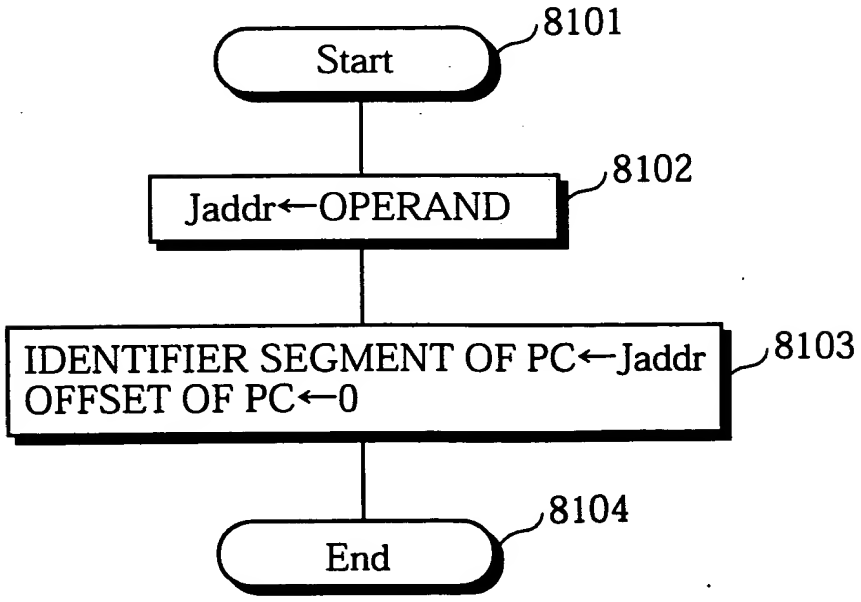

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FIG. 76

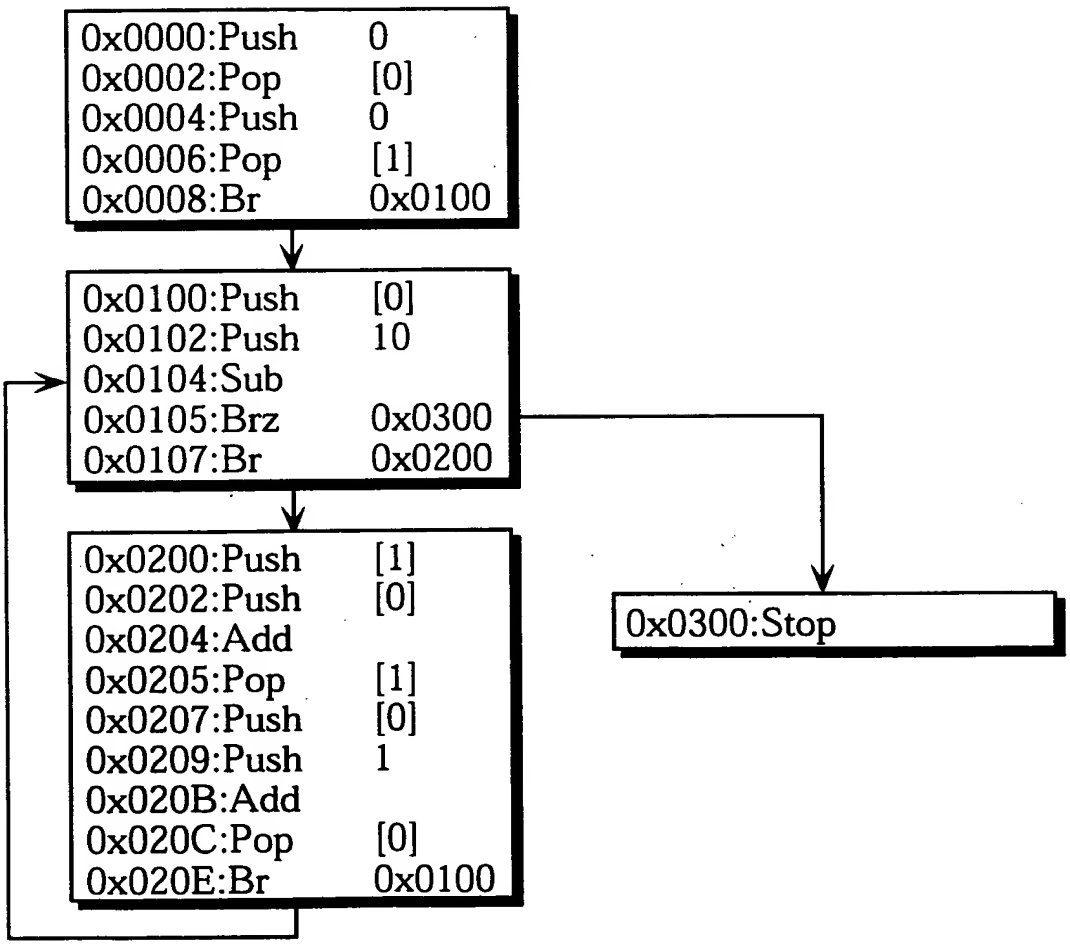

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FIG. 77

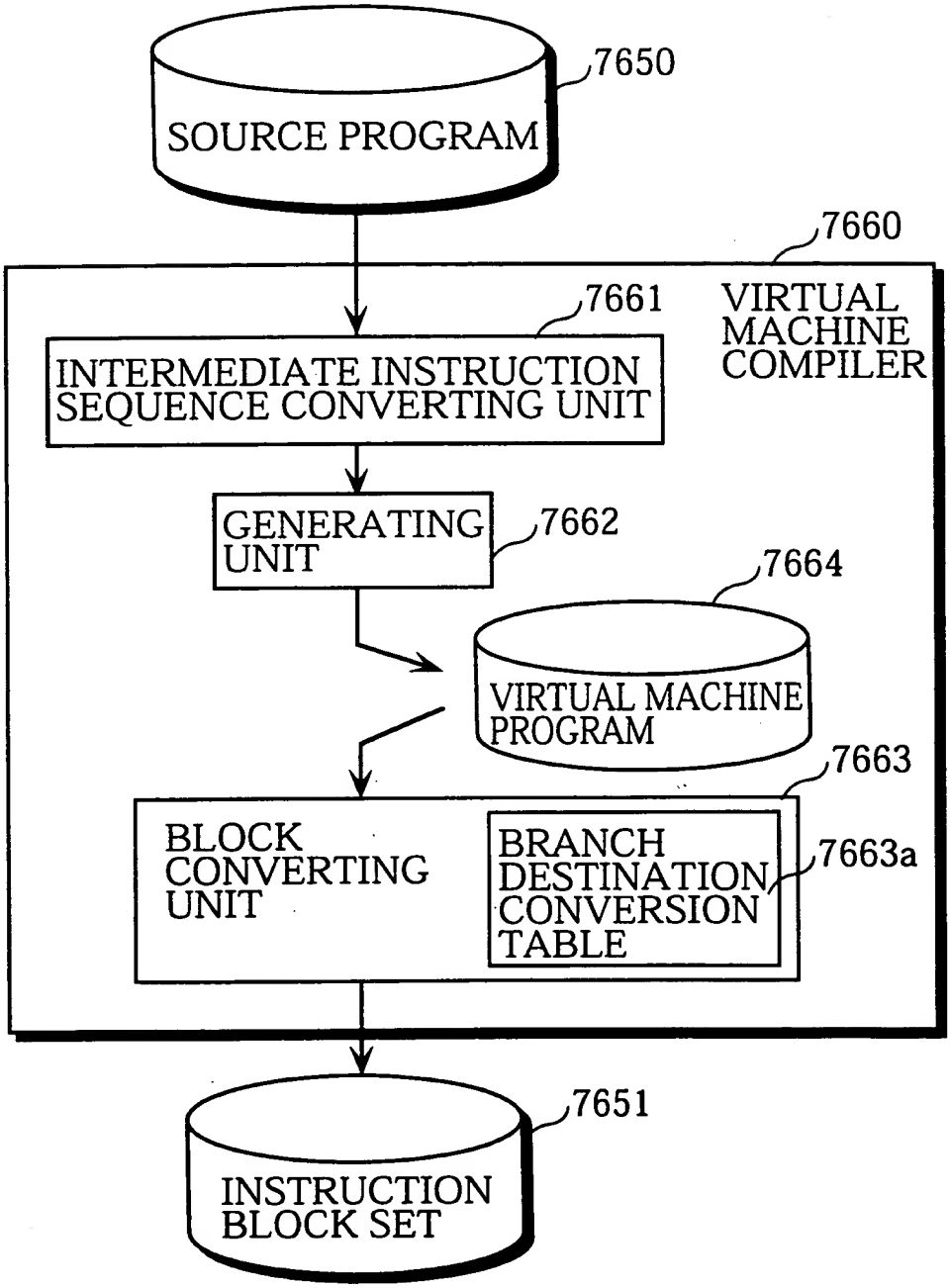

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FIG. 78

7663a

| | | | | |
|---|---|---|---|---|
| 0 | CODE POSITION : | REGISTRATION FLAG : | REFERENCE POSITION OFFSET : | REFERENCE POSITION IDENTIFIER : |
| 1 | CODE POSITION : | REGISTRATION FLAG : | REFERENCE POSITION OFFSET : | REFERENCE POSITION IDENTIFIER : |
| 2 | CODE POSITION : | REGISTRATION FLAG : | REFERENCE POSITION OFFSET : | REFERENCE POSITION IDENTIFIER : |
| 3 | CODE POSITION : | REGISTRATION FLAG : | REFERENCE POSITION OFFSET : | REFERENCE POSITION IDENTIFIER : |
| 4 | CODE POSITION : | REGISTRATION FLAG : | REFERENCE POSITION OFFSET : | REFERENCE POSITION IDENTIFIER : |
| | ⋮ | | | |
| Rcount-1 | CODE POSITION : | REGISTRATION FLAG : | REFERENCE POSITION OFFSET : | REFERENCE POSITION IDENTIFIER : |

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FIG. 79

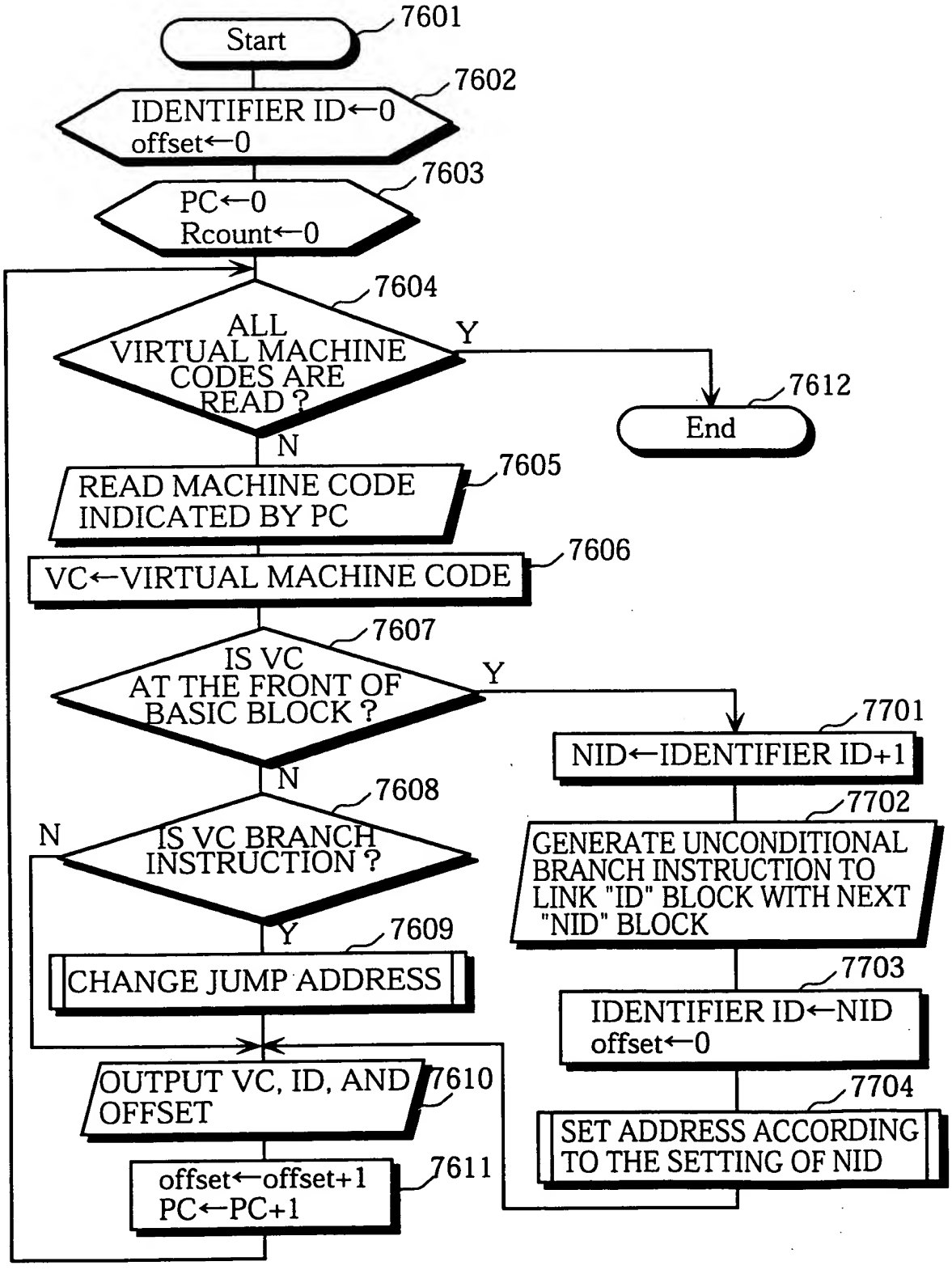

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FIG. 80

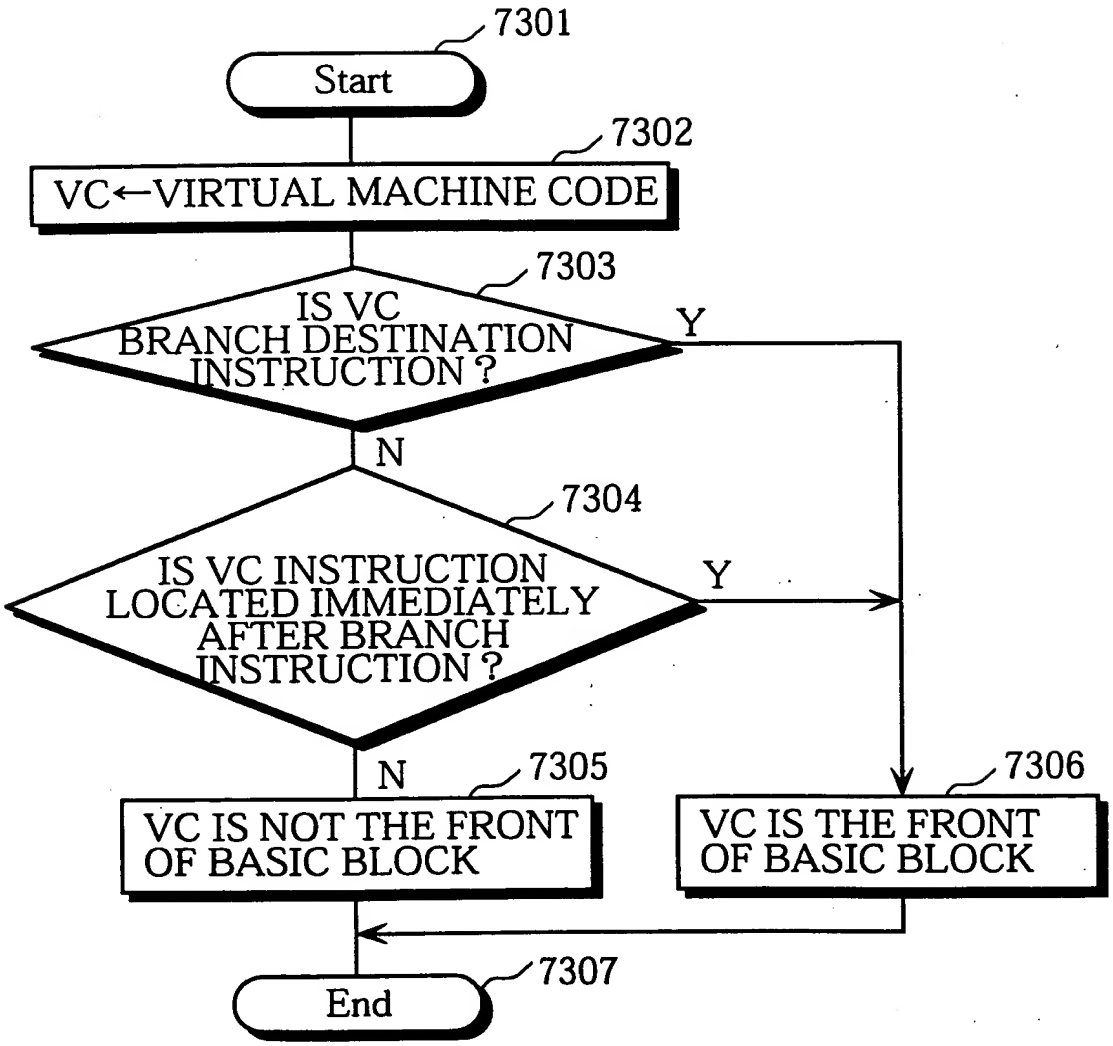

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FIG. 81

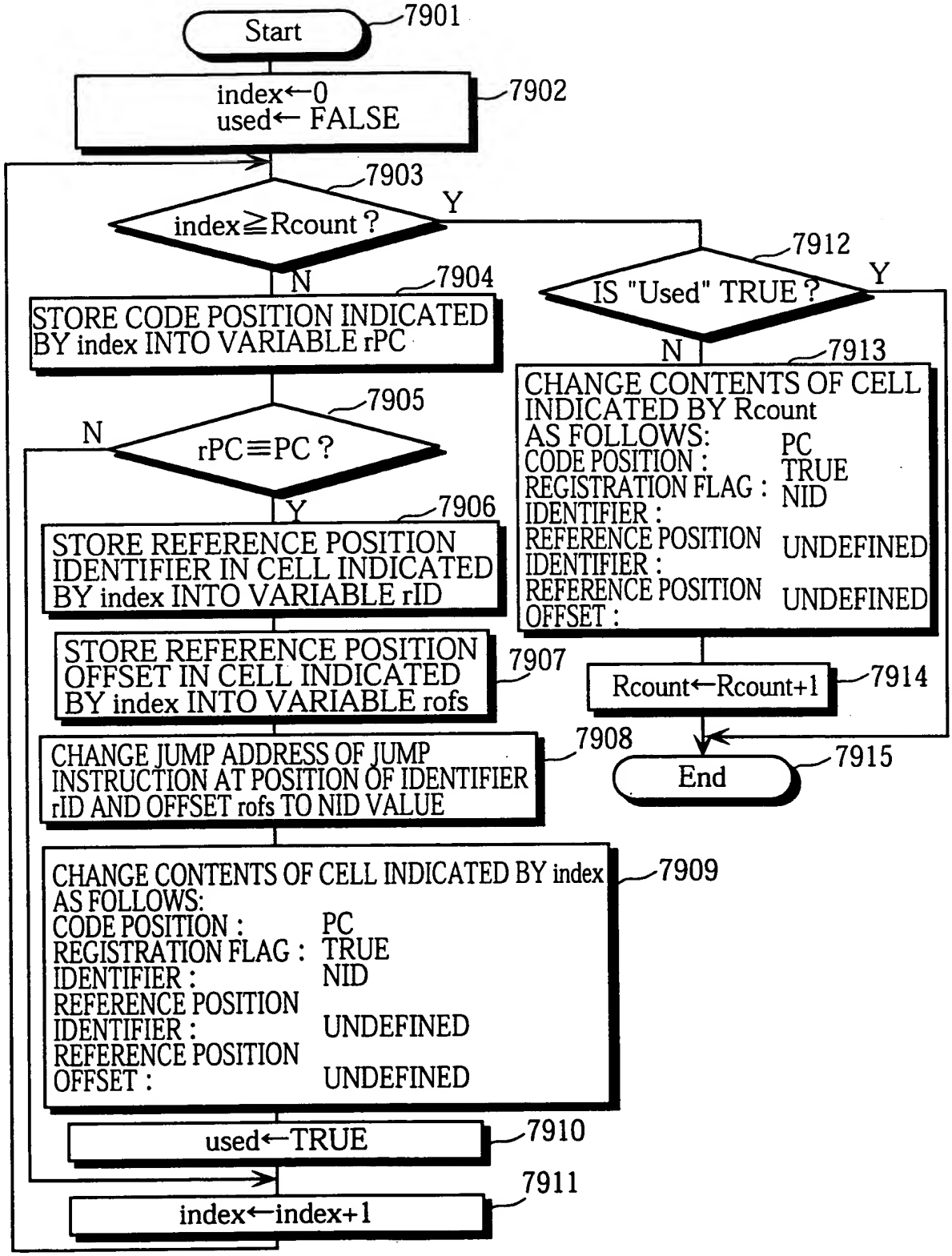

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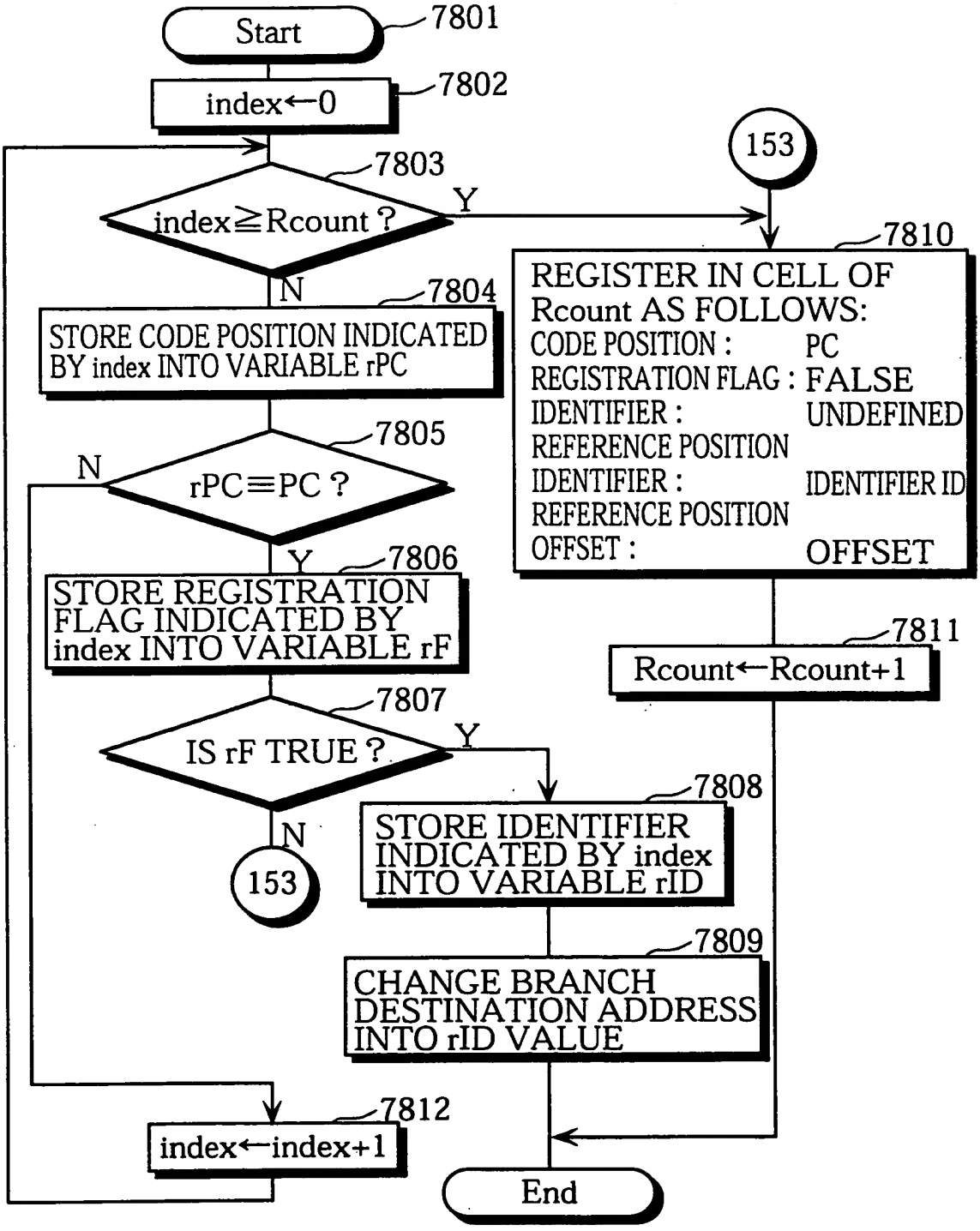
FIG. 82



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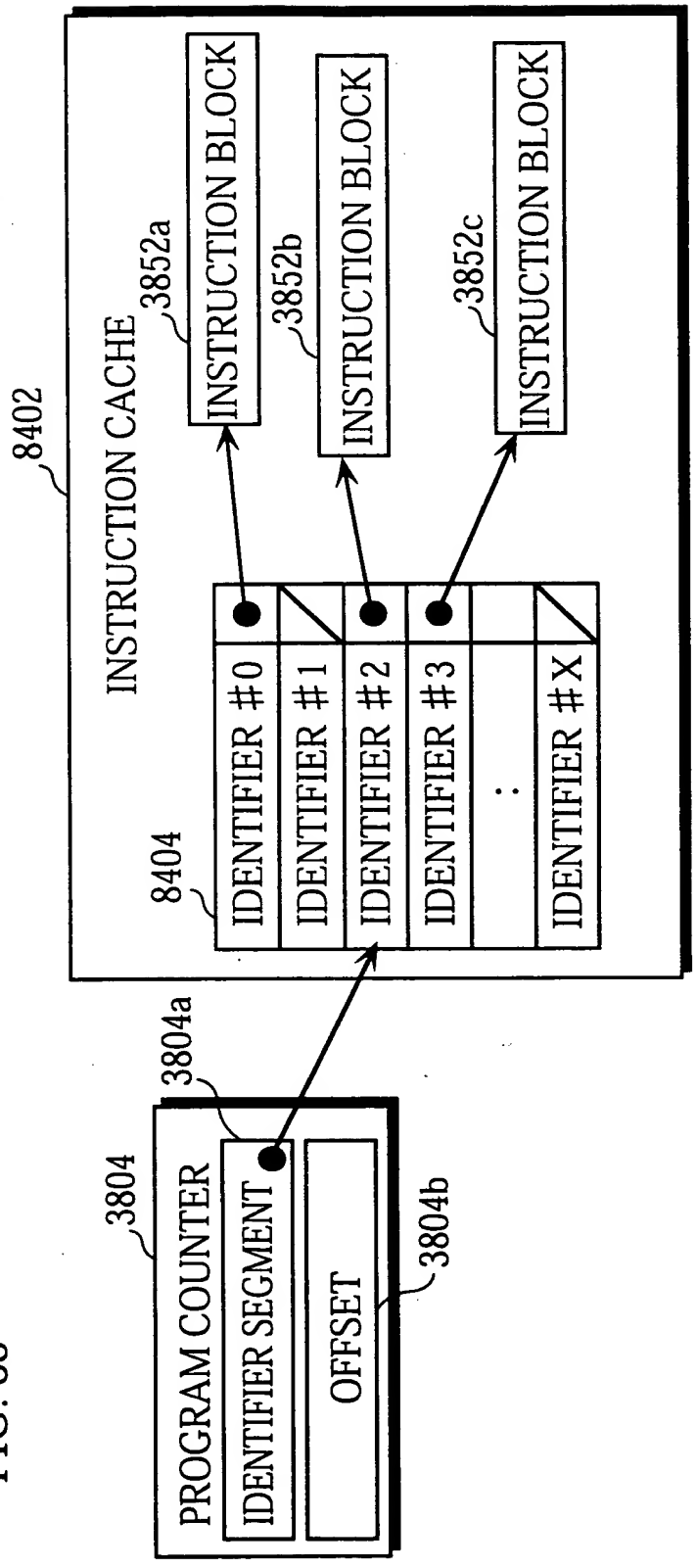


FIG. 83

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FIG. 84

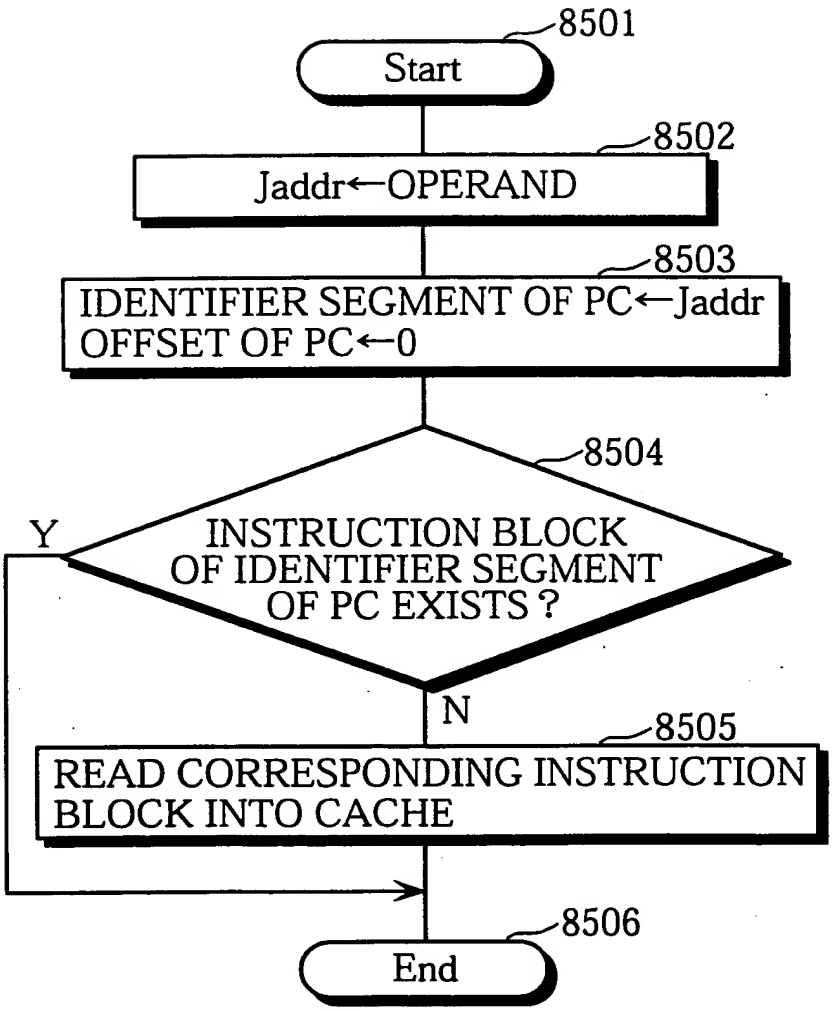

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FIG. 85

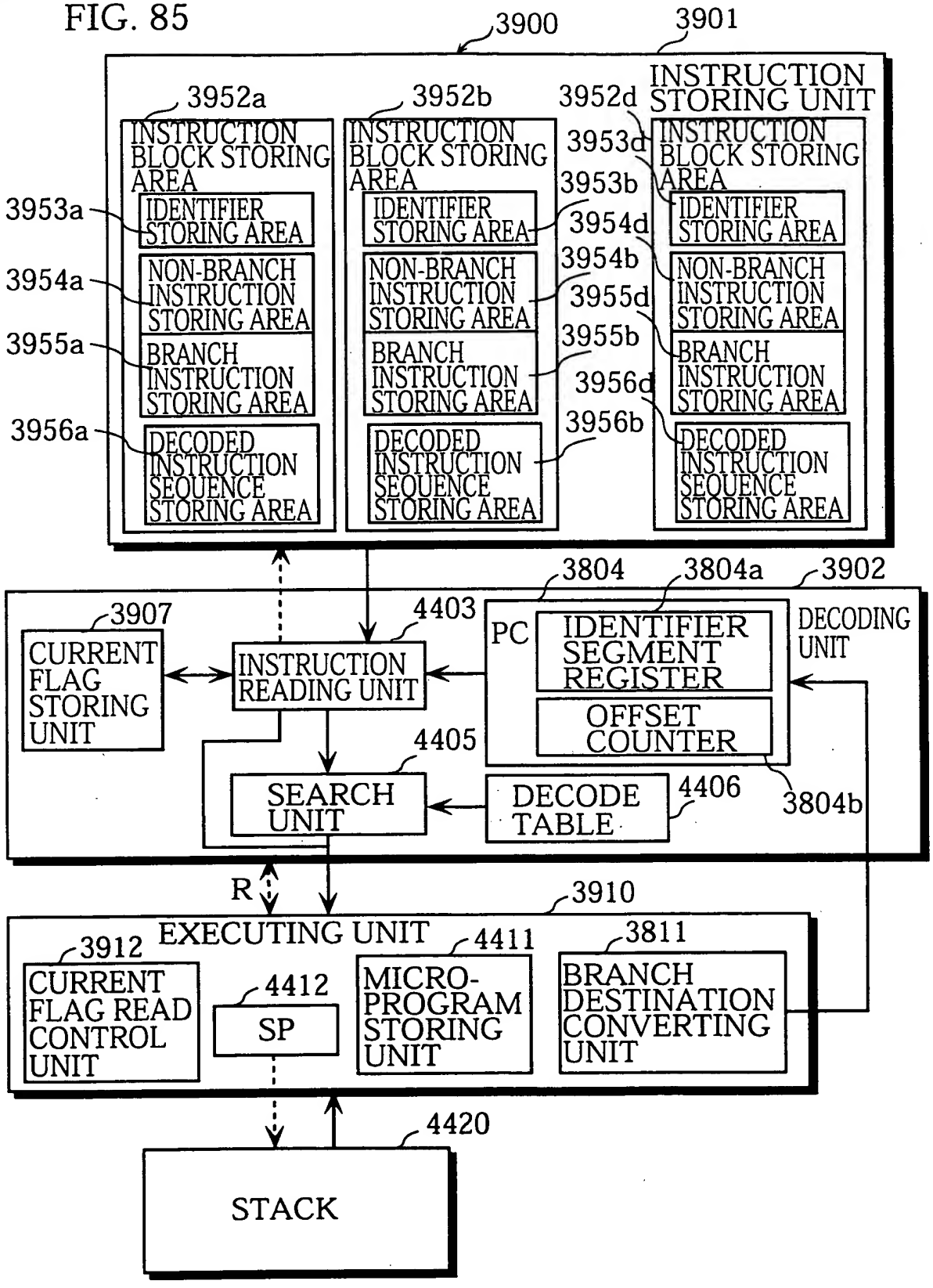

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FIG. 86A

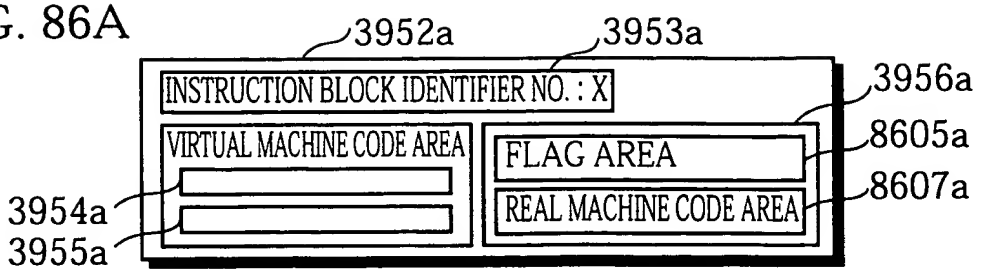


FIG. 86B

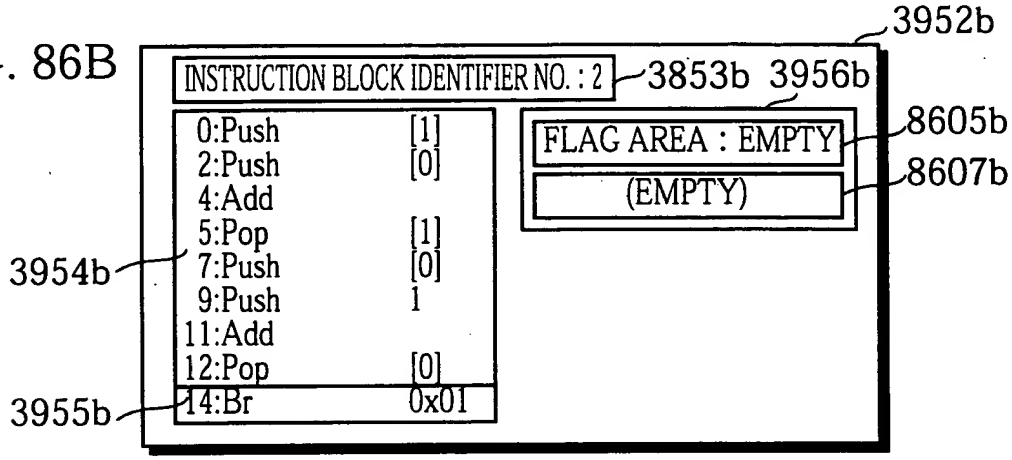


FIG. 86C

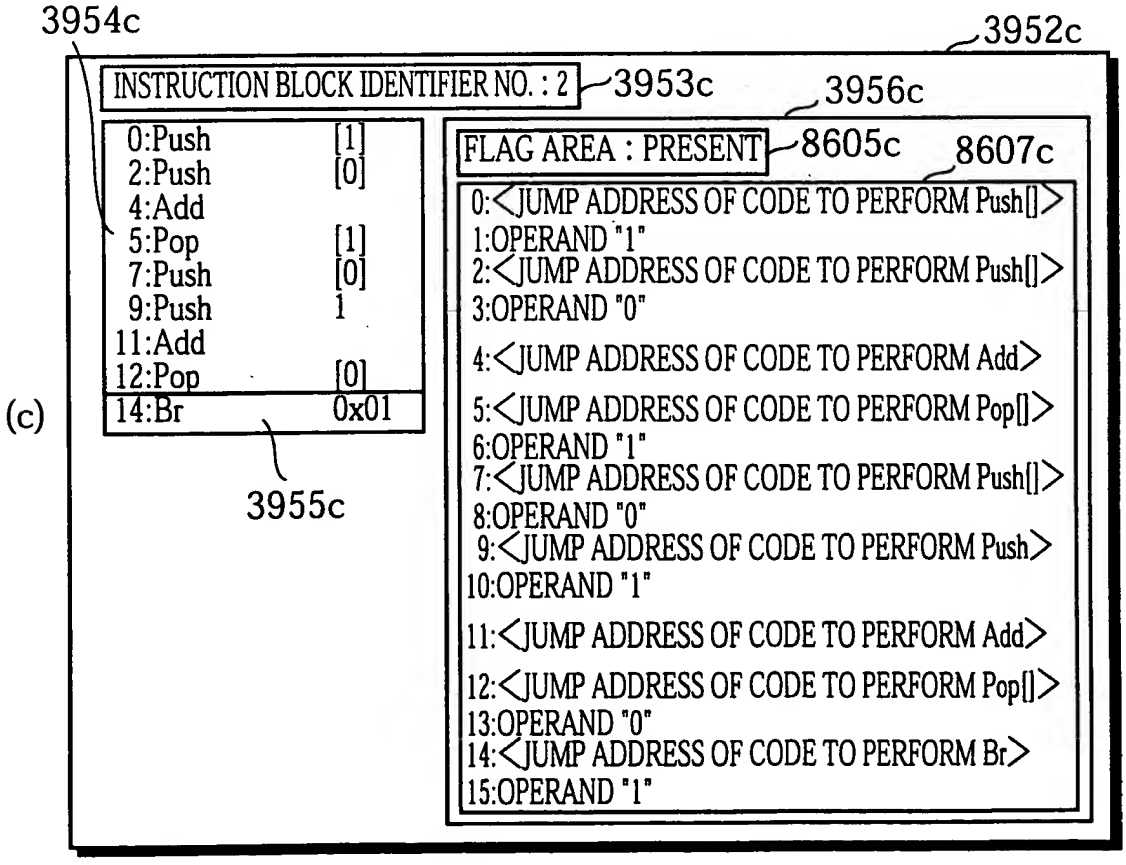

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FIG. 87

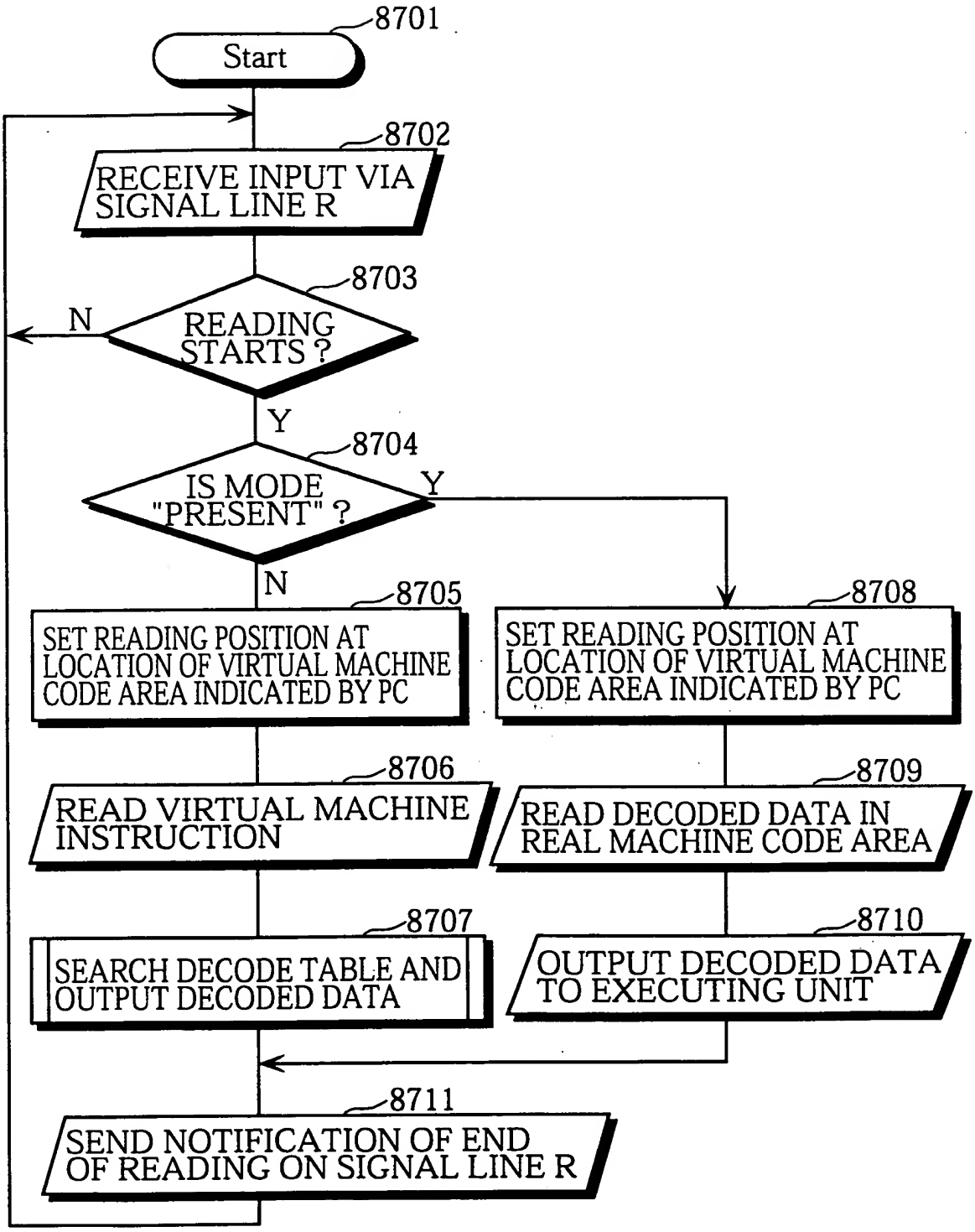

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FIG. 88

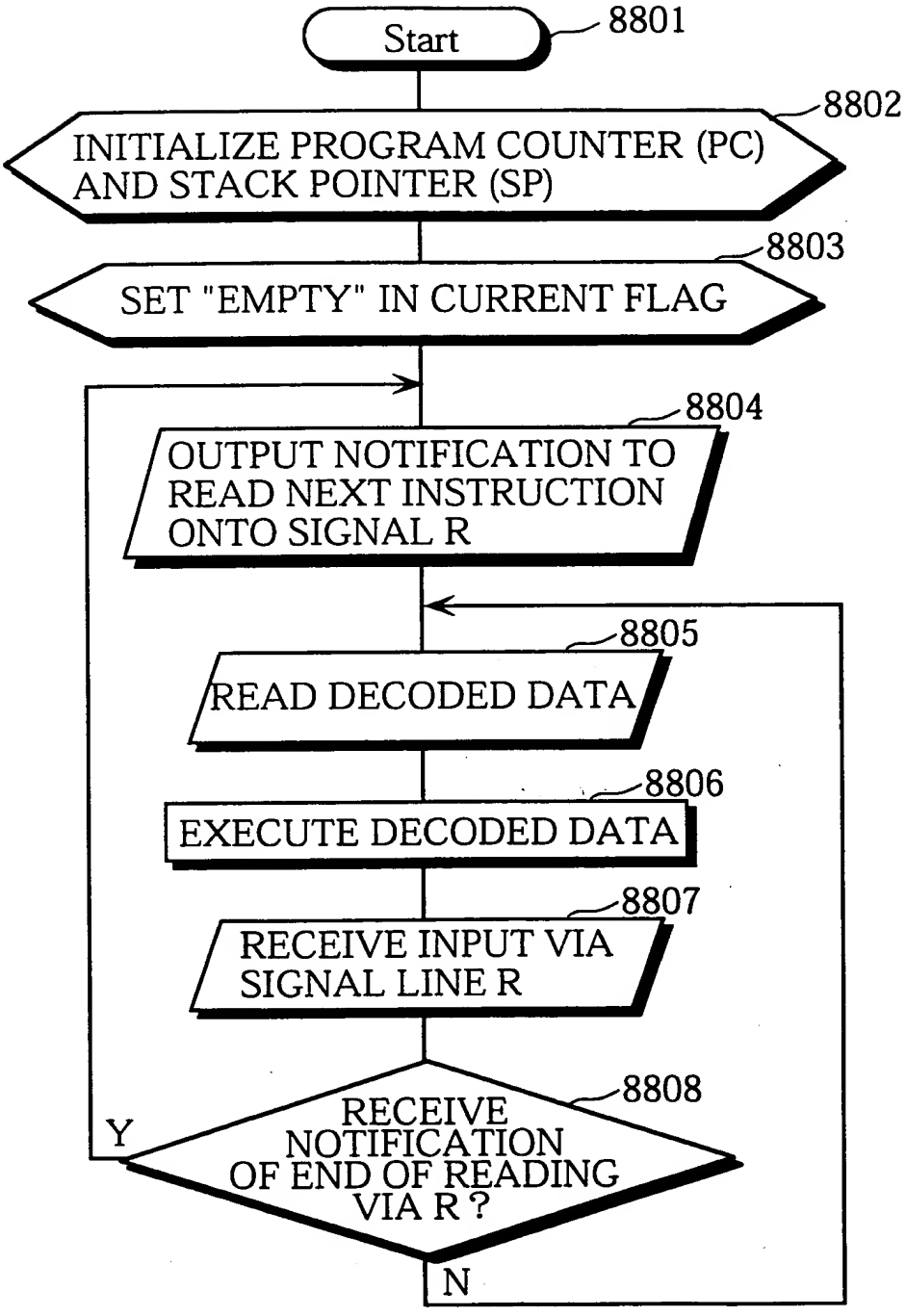

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FIG. 89

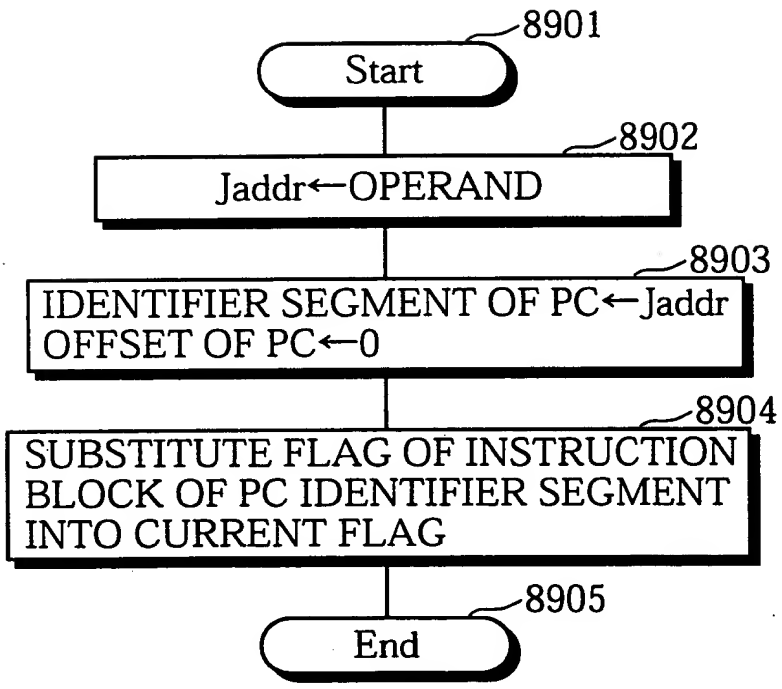

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FIG. 90

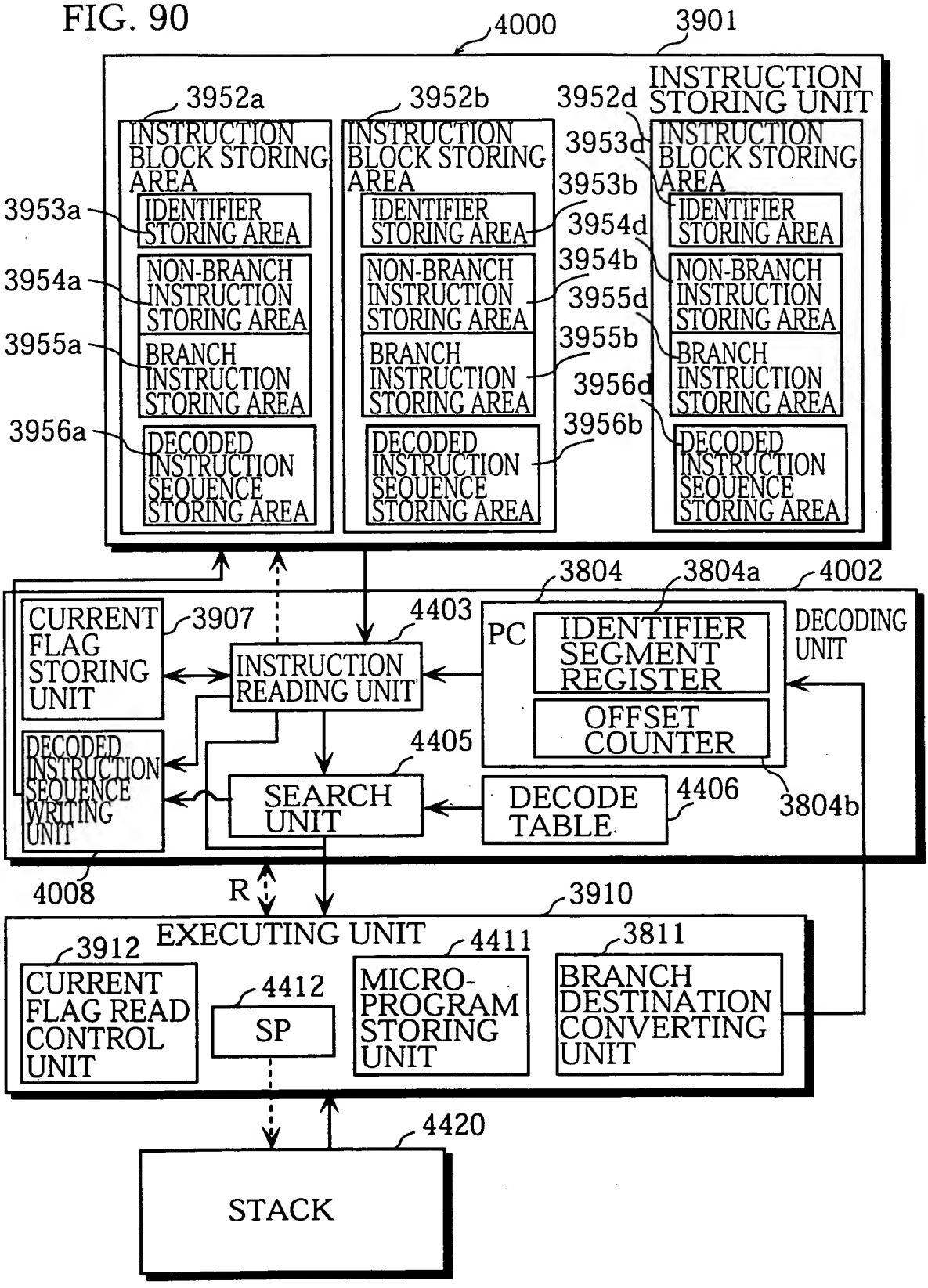

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FIG. 91

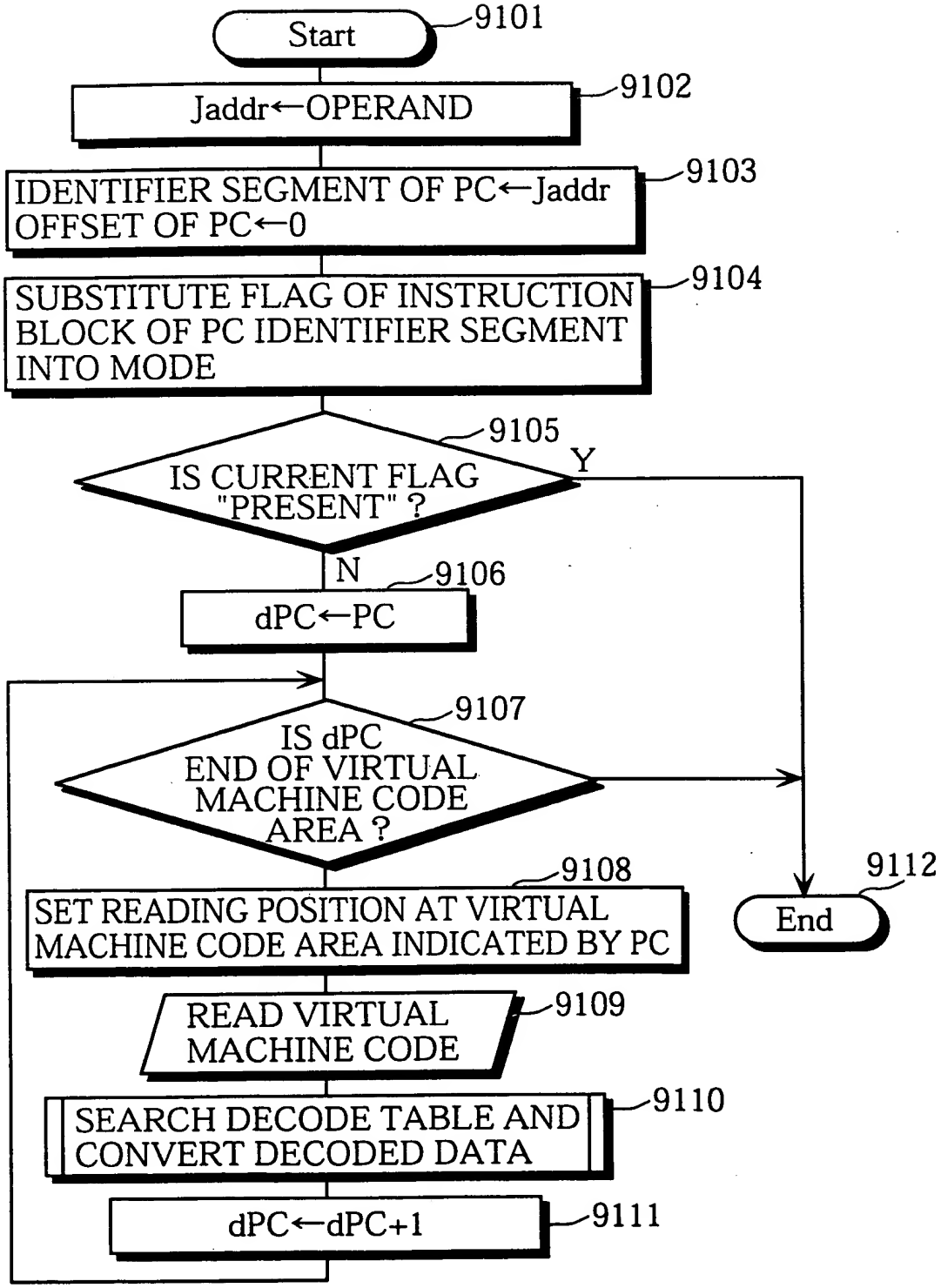

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FIG. 92

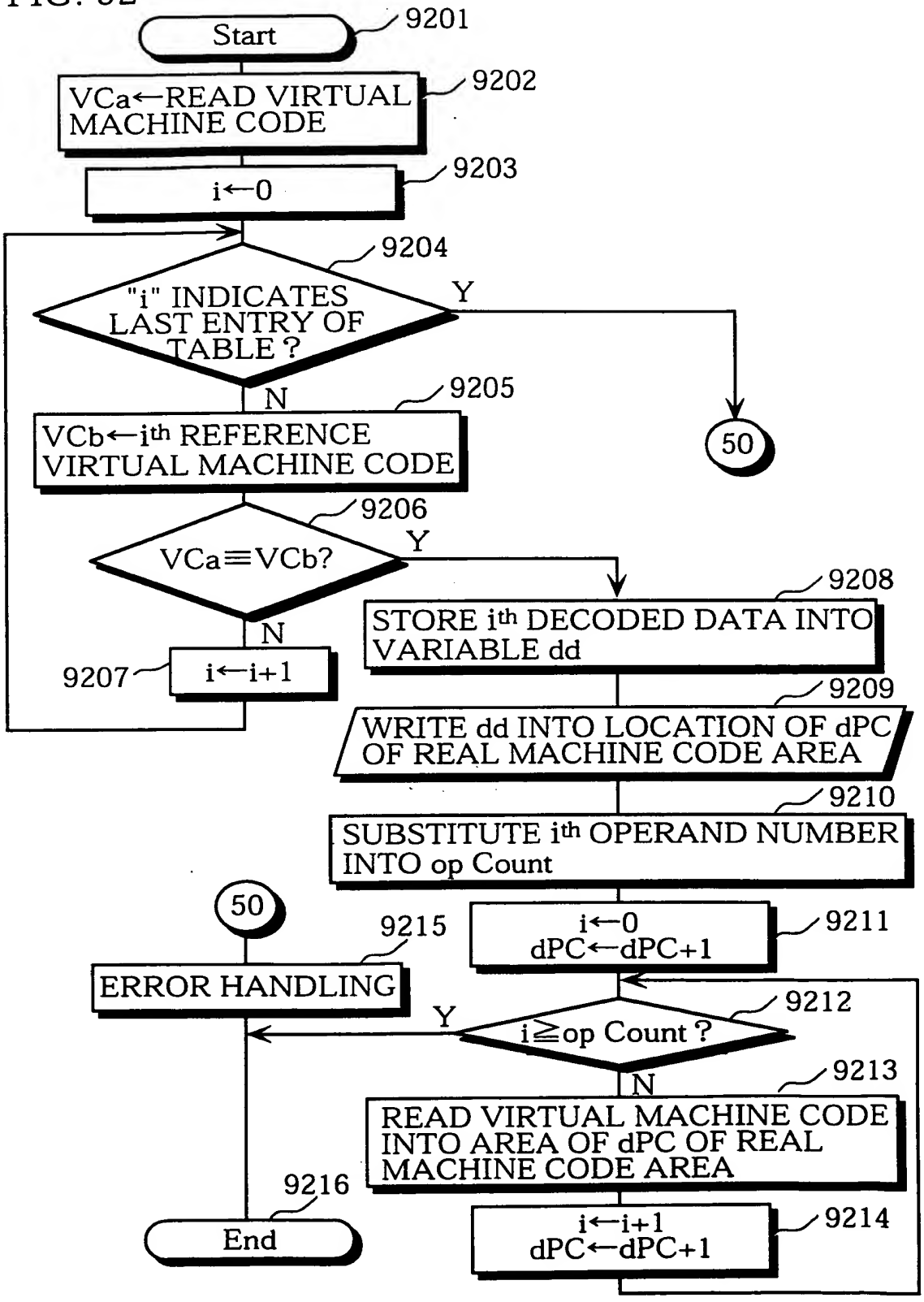

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FIG. 93

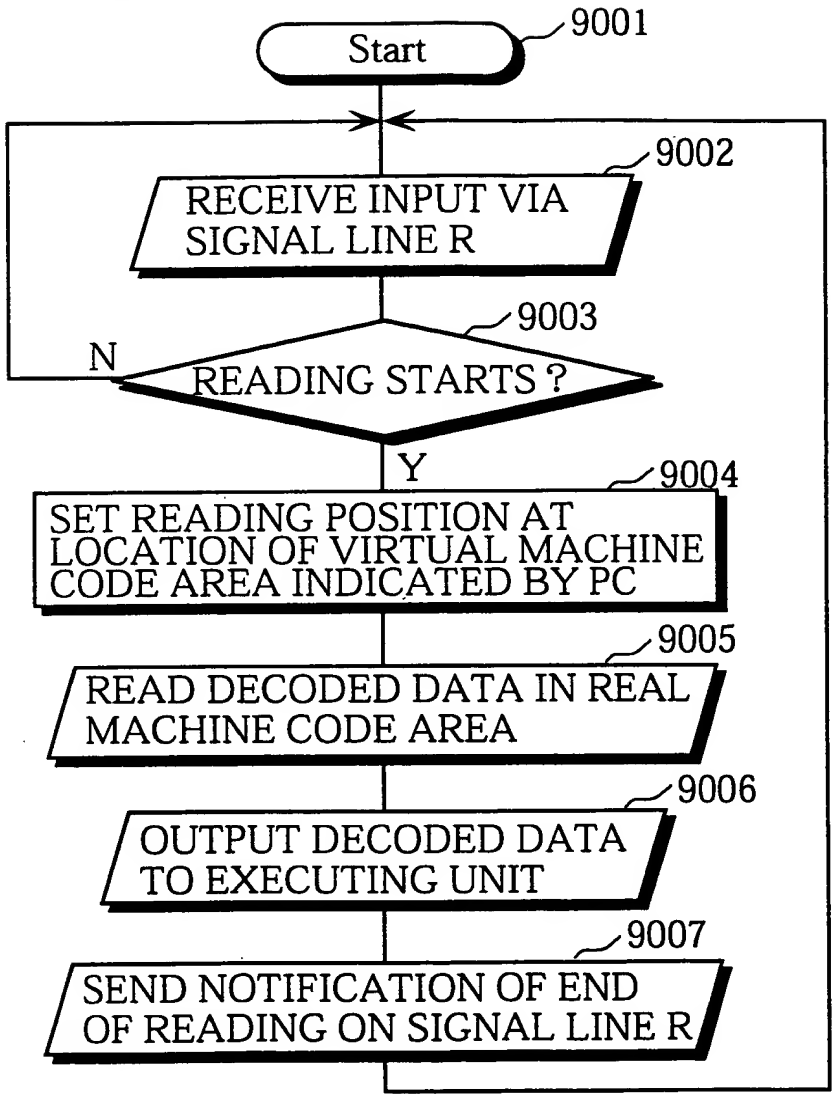

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FIG. 94

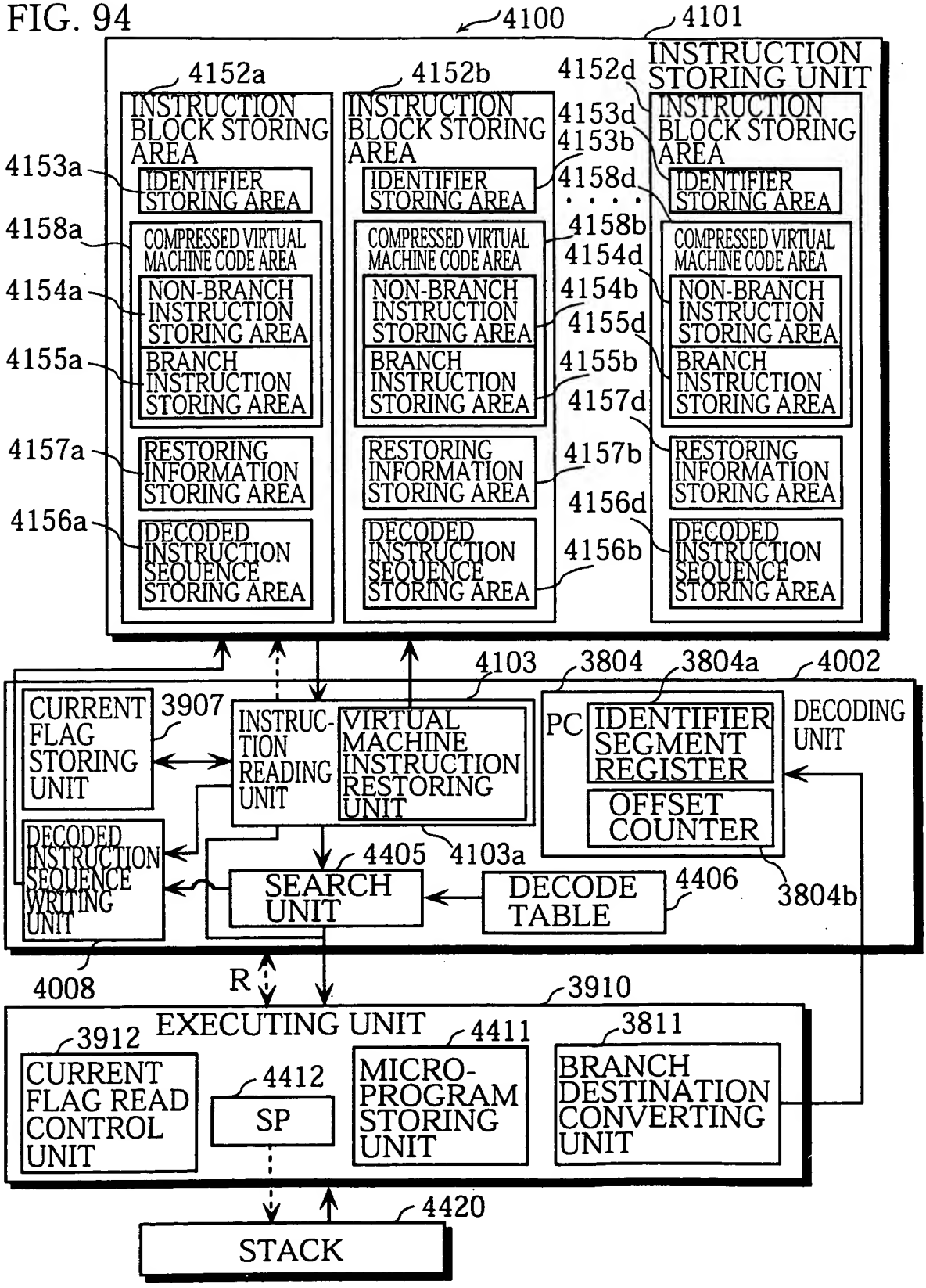

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FIG. 95A

| BIT SEQUENCE | VIRTUAL MACHINE INSTRUCTION |
|---|---|
| 000 | Push [0] |
| 100 | Push 0 |
| 101 | Pop [0] |
| 110 | Pop [1] |
| 111 | Br 0x01 |
| 0011 | Stop |
| 0100 | Add |
| 0110 | Brz 0x03 |
| 0111 | Br 0x02 |
| 00100 | Push [1] |
| 00101 | Push 1 |
| 01010 | Push 10 |
| 01011 | Sub |

FIG. 95B

| | | |
|---|---|---|
| Push | [0] | 000 |
| Push | [1] | 00100 |
| Push | 1 | 00101 |
| Stop | | 0011 |
| Add | | 0100 |
| Push | 10 | 01010 |
| Sub | | 01011 |
| Brz | 0x03 | 0110 |
| Br | 0x02 | 0111 |
| Push | 0 | 100 |
| Pop | [0] | 101 |
| Pop | [1] | 110 |
| Br | 0x01 | 111 |

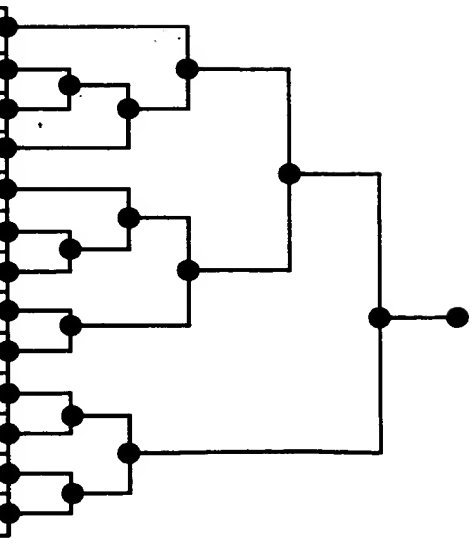

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FIG. 96A

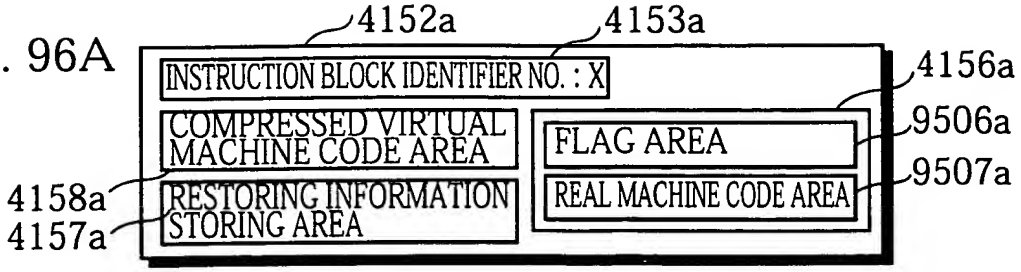


FIG. 96B

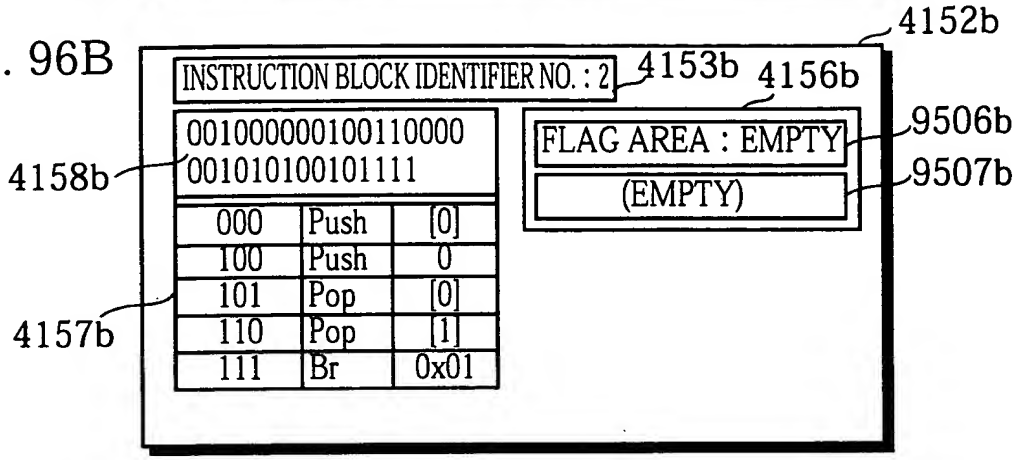


FIG. 96C

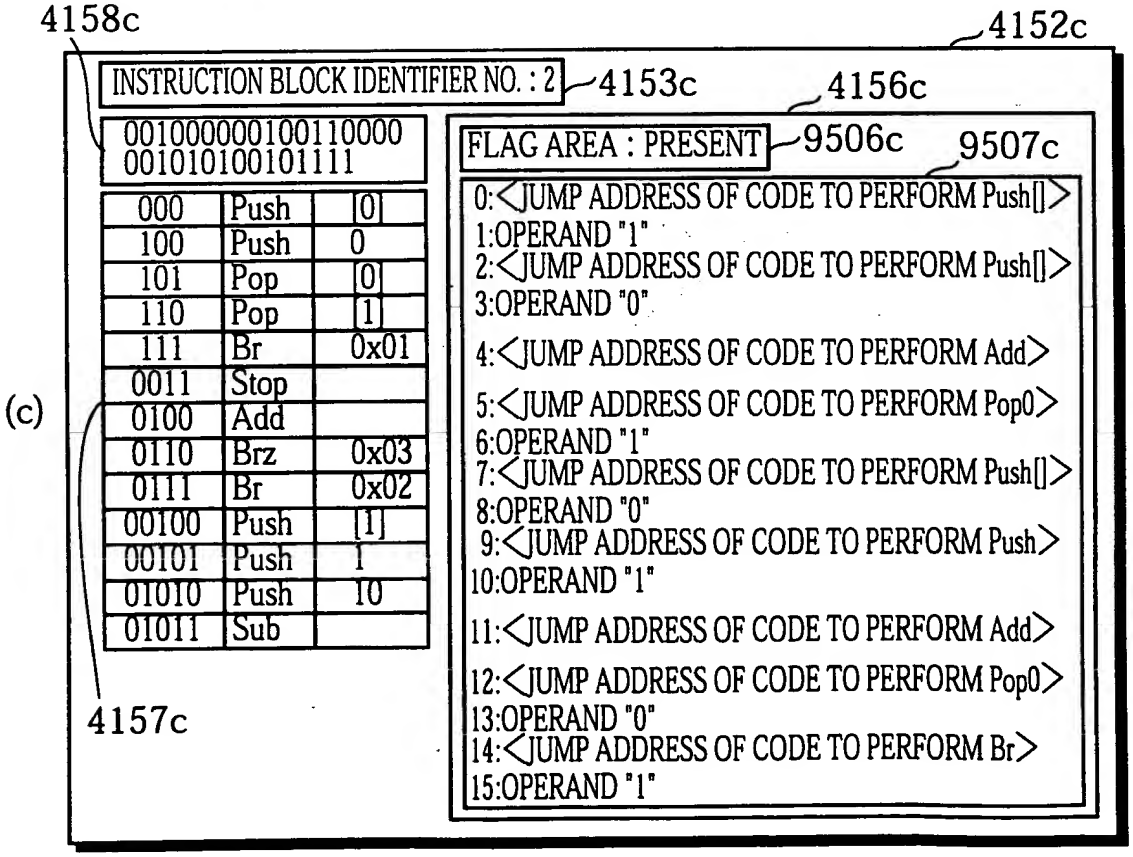

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FIG. 97

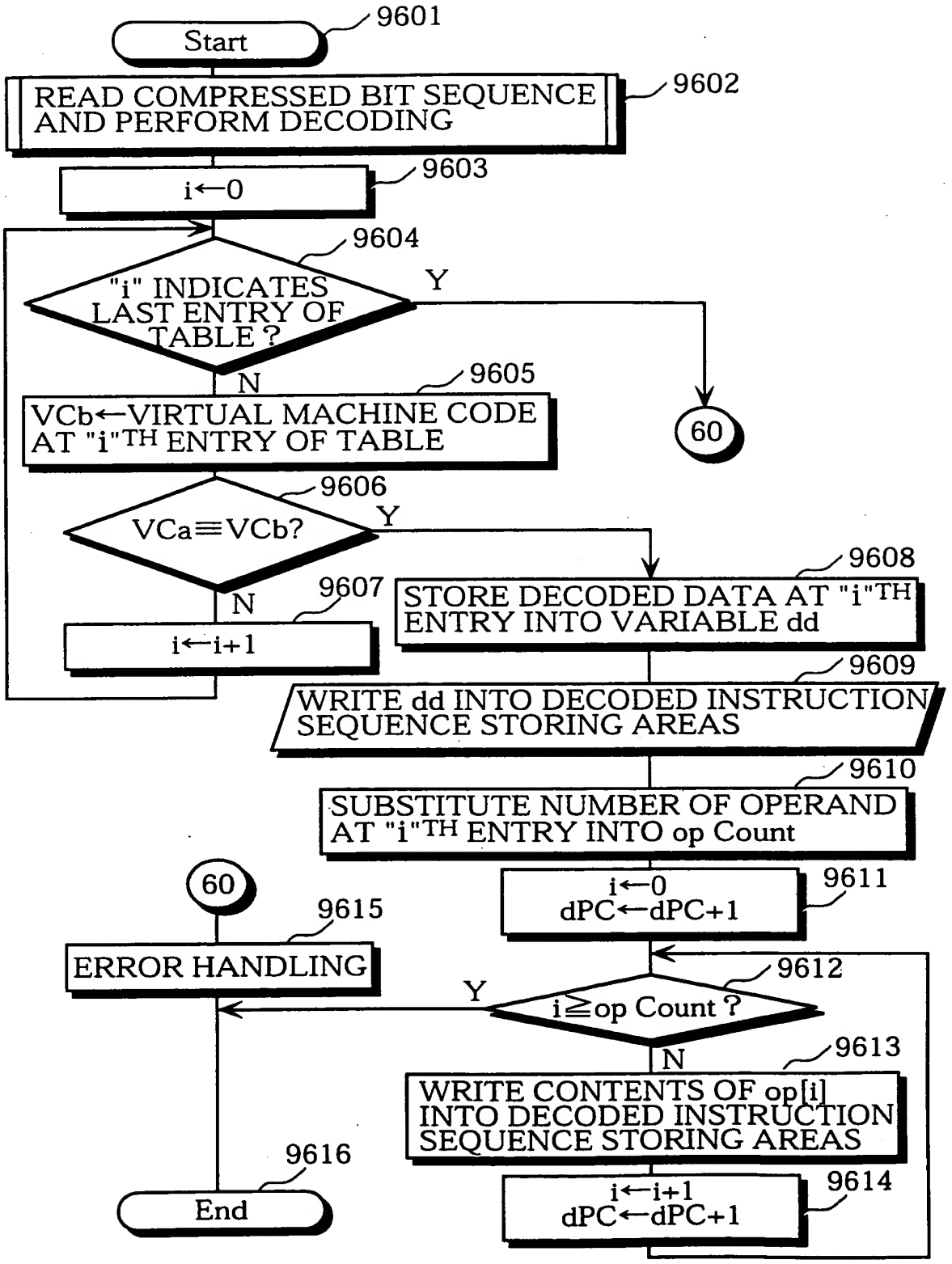

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FIG. 98

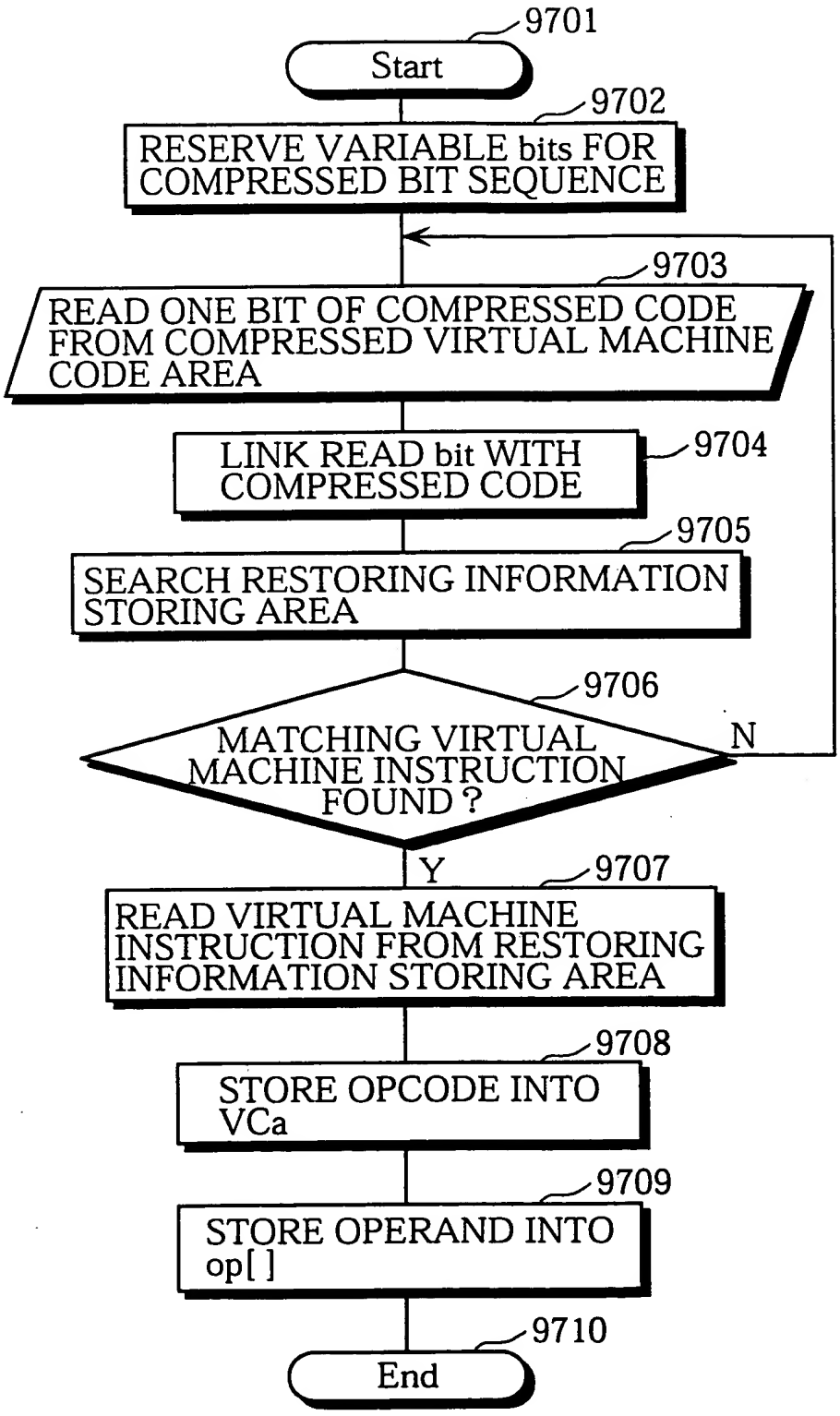

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FIG. 99

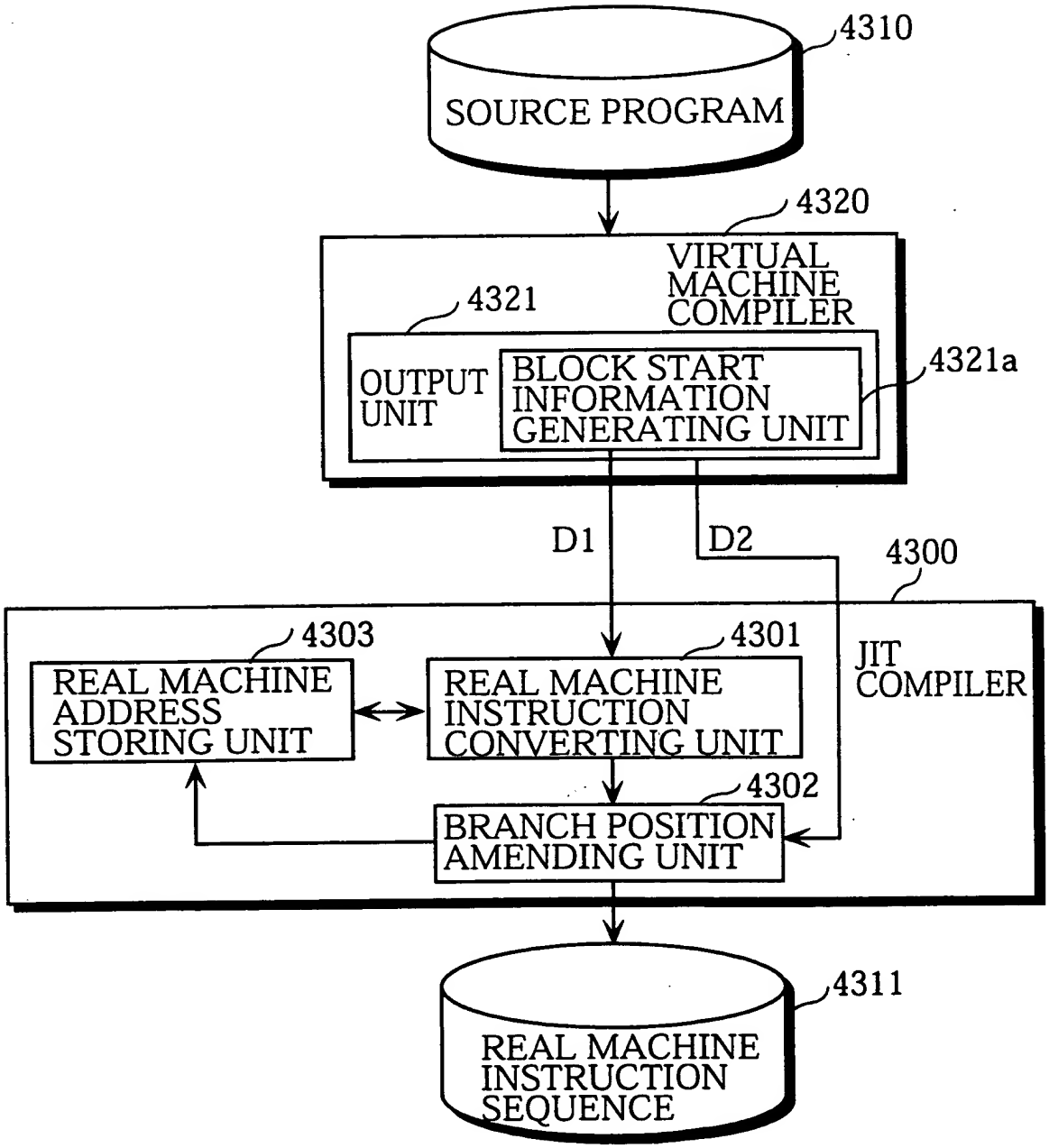

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FIG. 100

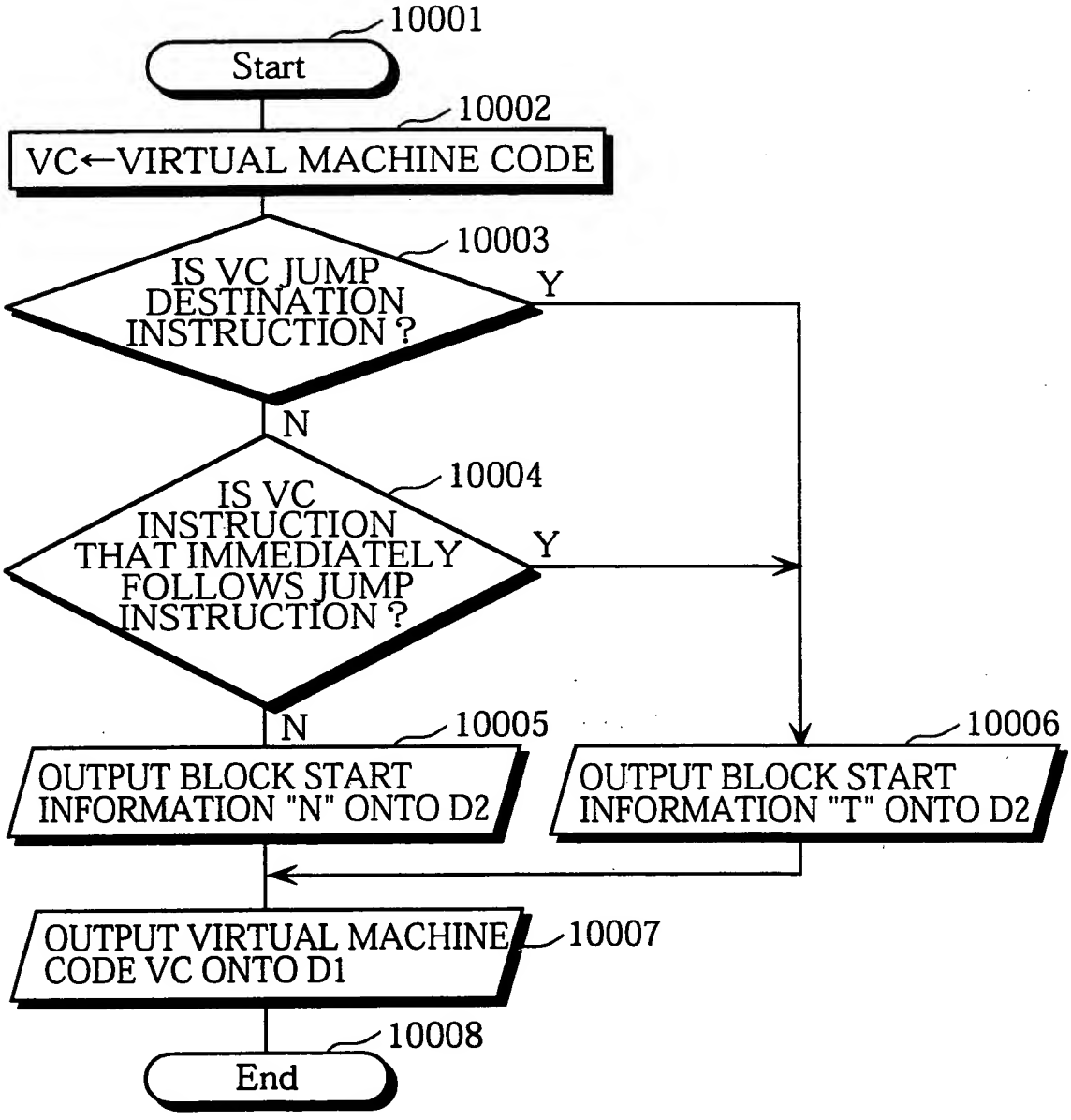

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FIG. 101

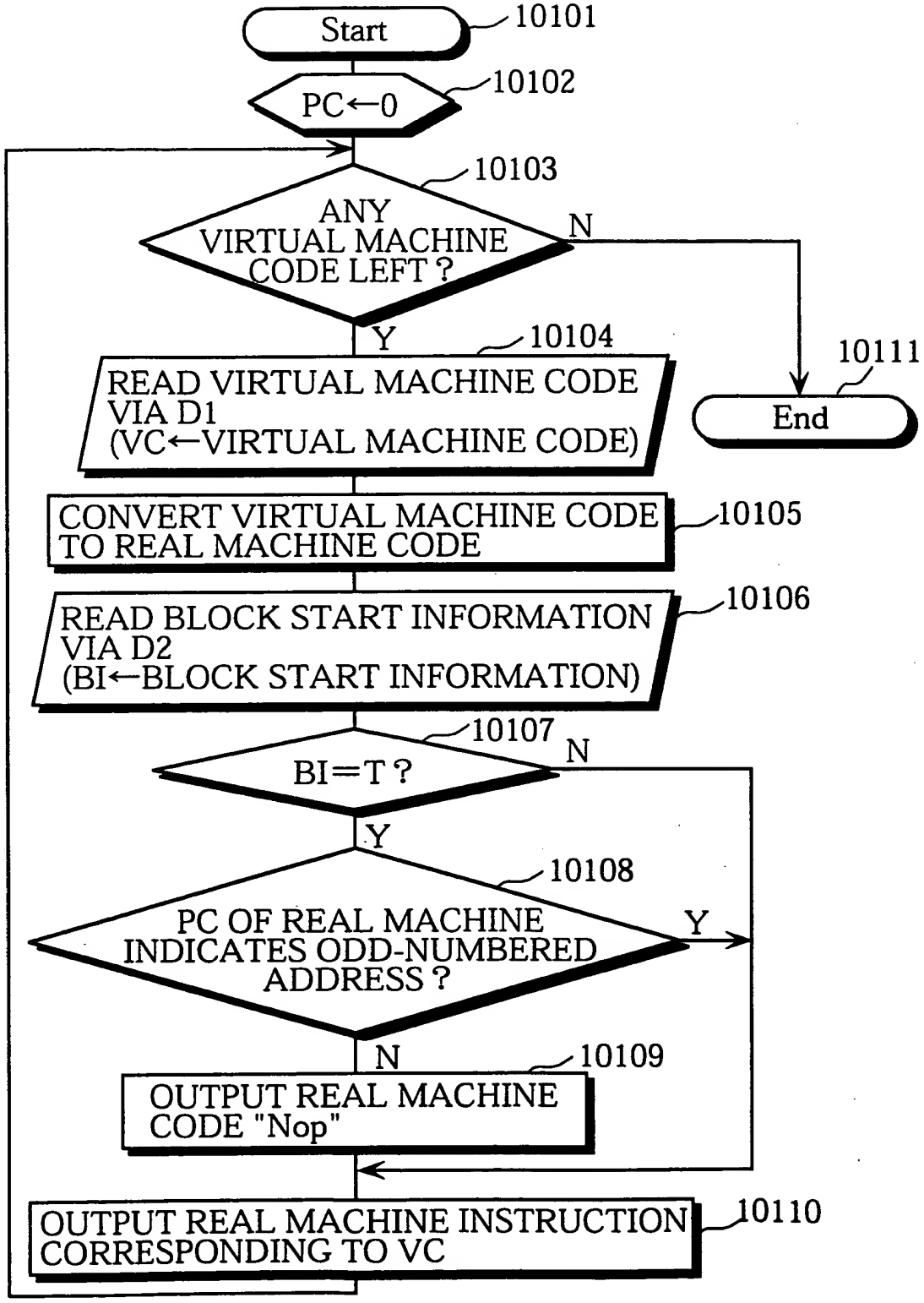

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FIG. 102

| ADDRESS | VIRTUL MACHINE CODE | REAL MACHINE CODE SIZE | CORRESPONDING REAL MACHINE CODE ADDRESS | BLOCK START INFORMATION | Nop OUTPUT |
|---|---|---|---|---|---|
| 0 | Push 0 | 4 | 0-3 | T | - |
| 2 | Pop [0] | 5 | 4-8 | N | - |
| 4 | Push 0 | 4 | 9-12 | N | - |
| 6 | Pop [1] | 5 | 13-17 | N | - |
| 8 | Push [0] | 5 | 18-22 | T | - |
| 10 | Push 10 | 4 | 23-26 | N | - |
| 12 | Sub | 3 | 27-29 | N | - |
| 13 | Brz 31 | 5 | 30-34 | N | Nop |
| 15 | Push [1] | 5 | 36-40 | T | - |
| 17 | Push [0] | 5 | 41-45 | N | - |
| 19 | Add | 3 | 46-48 | N | - |
| 20 | Pop [1] | 5 | 49-53 | N | - |
| 22 | Push [0] | 5 | 54-58 | N | - |
| 24 | Push 1 | 4 | 59-62 | N | - |
| 26 | Add | 3 | 63-65 | N | - |
| 27 | Pop [0] | 5 | 66-70 | N | - |
| 29 | Br 8 | 3 | 71-73 | N | - |
| 31 | Stop | 2 | 74-75 | T | - |

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FIG. 103

| U/D | N/T | VIRTUAL MACHINE OPCODE | OPERAND(S) |
|---|---|---|---|